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Team: Team MASS

Project: Rocket Recovery System

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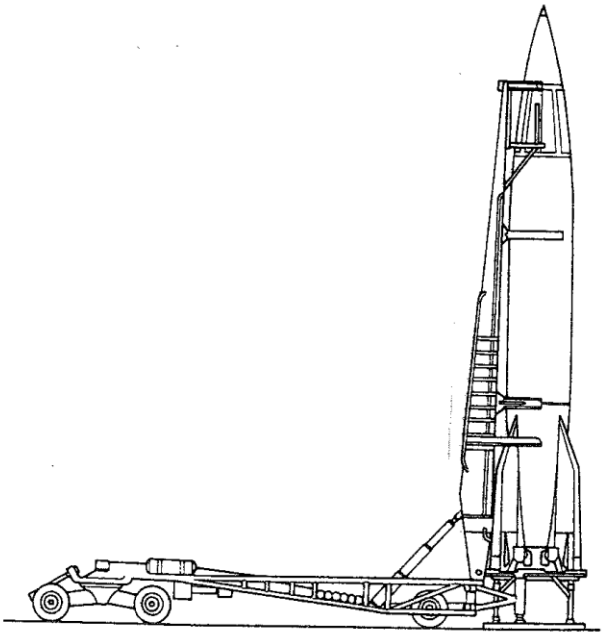

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Document Revision History

Revision Number	Revision Date	Description	Rationale
0.1	2/9/2013	Created Document	First version of the DDS
0.2	2/26/2013	Merged	Merged each branch of the document
0.3	2/26/2013	Final edits	Final QA inspection
1.0	2/26/2013	Submitted informal review	
2.0	2/26/2013	Submitted final edition	

1. - Introduction

1.1 - Document Overview

The Detailed Design Document will provide a low level description of the Rocket Recovery System. The document will provide information sufficient enough to begin a detailed design of the systems. The system will be divided into modules that provide the detail and functionality of each sub system. The modules will include information about inputs, outputs, data required, processing, and the pseudo code. The document will also include relationship mapping between various requirements and modules, quality assurance and testing considerations, and all specific details and design of all specific hardware parts.

1.2 - Project Scope and Overview

The Rocket Recovery System's central purpose is to launch a low powered model rocket and land it near the area where it was launched from. The Rocket Recovery System (RRS) has three components; The Intelligent Rotating Base Station (IRBS), The SD-12 Rocket, and the Rocket Recovery Module (RRM). The Intelligent Rotating Base Station is a launch pad that gathers information about the wind speed and direction using an attached anemometer. The IRBS will then compensate for the wind by rotating and tilting the launch pad in the appropriate direction. The IRBS will pass the wind data to the SD-12 Rocket equipped with the Rocket Recovery Module before launch. After the launch of the SD-12 rocket, the RRM will make real time calculations, using the IRBS data, to direct the rocket to a specified location. After the engine burn phase, a parachute will be deployed, and the SD-12 will float back to the coordinates where it was launched. The system will have an attached control launch box that the user interacts with the system with. This launch box is attached to the IRBS via a bus line.

The Rocket Recovery System will have three modes. These modes include: Standby Mode, Preparation Mode, and Launch Mode. The Standby mode will allow the user to attach the SD-12 rocket to the IRBS and make necessary adjustments. In this mode no data is being collected or used. The Preparation Mode will start to collect wind data from the attached anemometer, and make the adjustments to the IRBS. The Launch Mode will have the IRBS stop making adjustments, and start transmitting the aggregated wind data to the RRM. Once the SD-12 rocket receives all the information, the rocket is ready to launch.

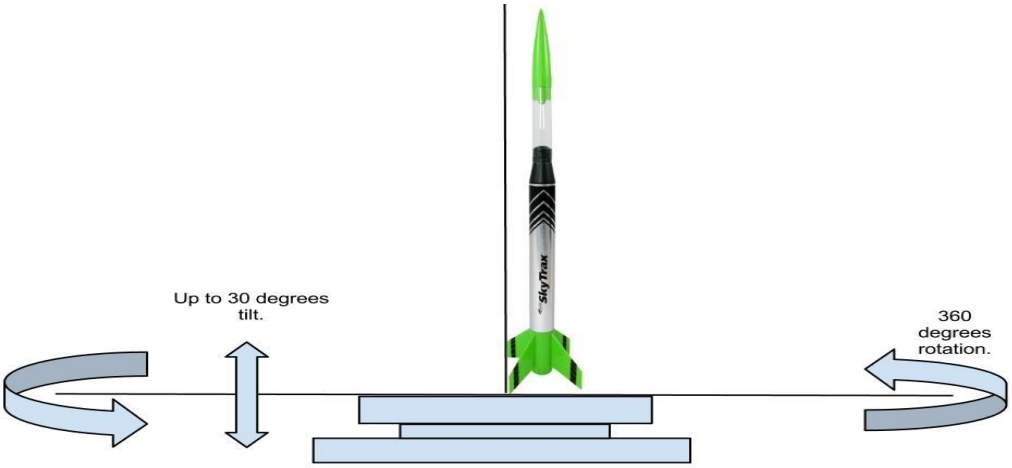

FIGURE 1-1 - ROCKET RECOVERY SYSTEM

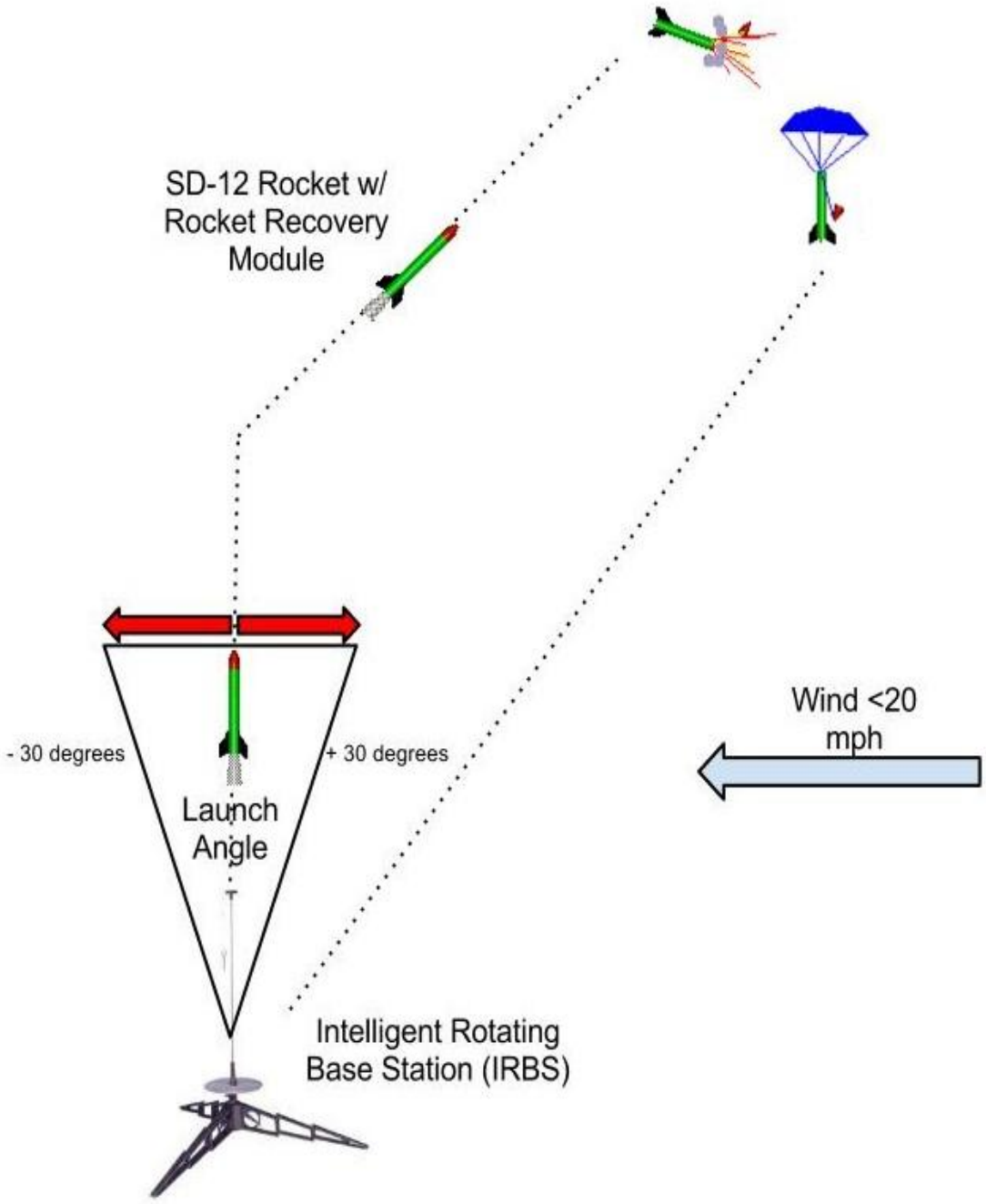

FIGURE 1-2-ROCKET RECOVERY SYSTEM

1.3 - Definitions and Acronyms

Term	Definition
RRM	Rocket Recovery Module
IRBS	Intelligent Rotating Base Station
SD-12	The actual rocket that will have the Rocket Recovery Module inside of it
LCD	Liquid Crystal Display
LED	Light Emitting Diode
OS	Operating System

TABLE 1.1- DEFINITIONS AND ACRONYMS

2. - Architecture Overview

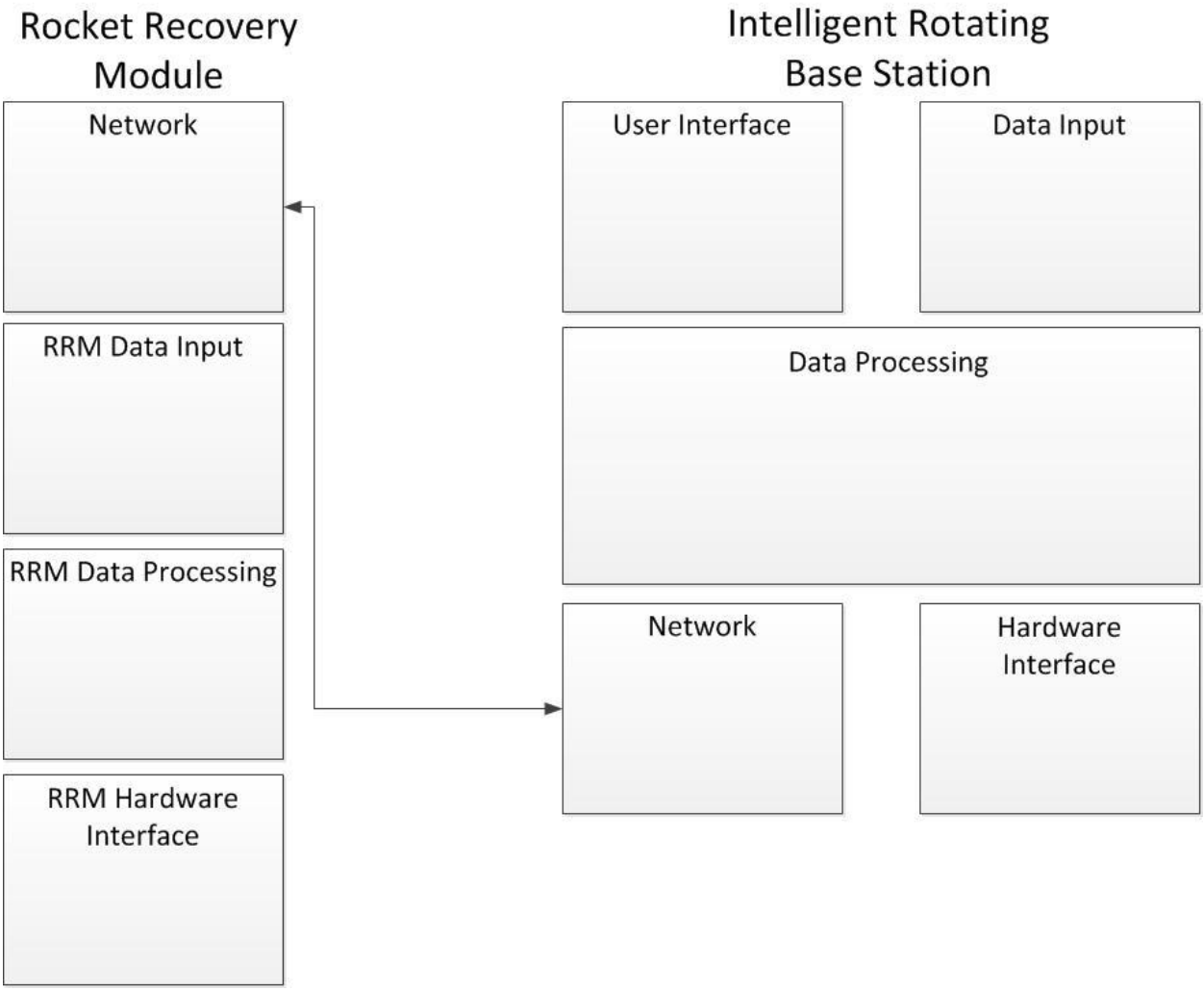

FIGURE 5-2-1- ARCHITECTURE OVERVIEW

2.1 - Overview

The Rocket Recovery System is divided in to 2 separate systems. The intelligent Rotating Base Station is dived further into 5 separate layers; The User Interface, The Data Input, The Data Processing, The Hardware Interface, and The Network Layer. The Rocket Recovery Module is dived into 4 distinct layers; The Network, The RRM Data Input, The RRM Data Processing, and The RRM Hardware Interface.

2.2 - The Intelligent Rotating Base Station

2.2.1 - **User Interface**

The IRBS User Interface Layer is responsible for allowing the user to visually interact with the system. This layer allows the user to see what user input has been entered and what data has been collected and processed. This layer consists of two subsystems; Get Data and Display Output.

2.2.2 - **Data Input**

The IRBS Data Input Layer is responsible for handling the user input, the anemometer input, and the accelerometer. The IRBS Data Input layer consists of three subsystems, the User Input, the Anemometer Input, and the Accelerometer Input.

2.2.3 - **Data Processing**

The IRBS Data Processing Layer's purpose is to emphasize modularity in the design structure of the system. All processing of data will be encapsulated within this layer and the resulting comprehendible data will be made available to the respective systems, the hardware layer, the user interface layer, and the network layer.

2.2.4 - **Hardware Interface**

The IRBS Hardware Layer is responsible for obtaining the data that will be used by the servo to rotate at a specific angle depending on the speed of the wind.

2.2.5 - **Network**

The IRBS Network layer is the last layer of the IRBS system and retrieves data from the IRBS Data Processing Layer. The layer either de-multiplexes or multiplexes the data with the RRM Network layer. IRBS Network layer consists of Send/Receive Subsystem and Get Data Subsystem.

2.3 - The Rocket Recovery System

2.3.1 - **Network**

The RRM Network Layer is the first layer of the RRM system, and it connects RRM system with the IRBS system. The layer either multiplexes or de-multiplexes the data with the IRBS Network layer. RRM Network layer consists of Send Data Subsystem and Receive Data Subsystem.

2.3.2 - **RRM Data Input**

The RRM Data Input Layer is responsible for handling the input data from the accelerometer, barometer, and the processed data from Network Layer. The RRM Data Input layer consists of three subsystems; The Accelerometer Input, The Barometer input, and the IRBS Processed Input.

2.3.3 - **RRM Data Processing**

The purpose of the RRM Data Processing Layer is to emphasize modularity in the design structure of the system. All processing of data will be encapsulated within this layer and the resulting comprehendible data will be made available to the hardware layer.

2.3.4 - **RRM Hardware Interface**

The RRM Hardware Layer is responsible for obtaining the air pressure and acceleration data from the RRM Data Process layer in determine the stability of the rocket and the servo opening for the landing.

2.4 - IRBS Module Decomposition

2.4.1 - **Overview**

The main purpose of DDS was to break down each sub system into modules. This section contains the high level definition of each module that we have in the IRBS system.

2.4.2 - **Module Chart**

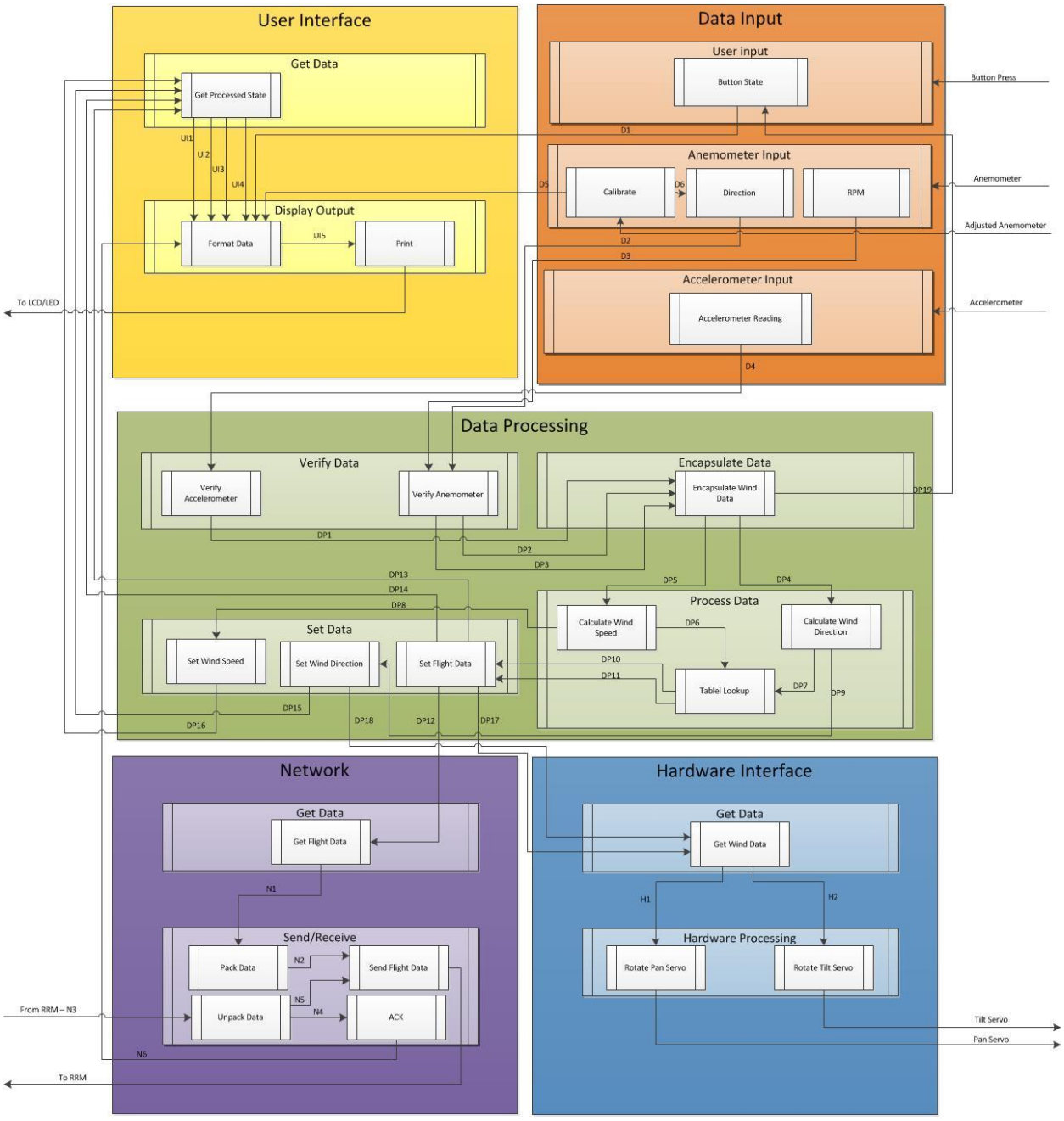

FIGURE 2-2- IRBS MODULE CHART

Data Element	Data Description
D1	The change in buttons current state.
D2	An integer that contains the wind direction (0 to 360) data.
D3	A long that contains the wind speed in mph.
D4	Integer values that contain the orientation values for x, y, z.
D5	A String that contains the confirmation message that the anemometer has been calibrated.

D6	New low and high values using the Arduino's map() function.
DP1	Integer values that contain the values for x, y, z and has been error checked.
DP2	An integer that contains the wind direction (0 to 360) data and has been error checked.
DP3	A long that contains the wind speed in mph and has been error checked.
DP4	An integer array that contains the aggregate of collected wind direction data.
DP5	A Long data type array that contains the aggregate of collected wind speed data.
DP6	A float that contains the average wind speed.
DP7	A float that contains the average wind direction.
DP8	A float that contains the average wind speed. Final value set for storage
DP9	A float that contains the average wind direction. Final value set for storage
DP10	An integer that contains the rocket turn altitude. Final value set for storage
DP11	A float that contains the launch pad angle. Final value set for storage
DP12	An integer that contains the rocket turn altitude.
DP13	An integer that contains the rocket turn altitude.
DP14	A float that contains the launch pad angle.
DP15	A float that contains the average wind direction.
DP16	A float that contains the average wind speed.
DP17	A float that contains the launch pad angle.
DP18	A float that contains the average wind direction.
DP19	A Boolean data type containing the pad over tilt safety function.
H1	A float that contains the average wind direction.
H2	A float that contains the launch pad angle
N1	An integer that contains the rocket turn altitude.
N2	A struct that contains an integer that contains the rocket turn altitude.
N3	A acknowledgement struct.
N4	A boolean value from the struct determining whether the data is sent or not.
N5	A boolean value from the struct determining whether the data is sent or not.
N6	A boolean value from the struct determining whether the data is sent or not.
UI1	A float that contains the average wind direction.
UI2	A float that contains the average wind speed.
UI3	An integer value that contains the altitude
UI4	A float value that contains the pad angle
UI5	A string of all the formatted data for display.

TABLE 2.1 - IRBS MODULE DATA FLOWS

		Consumer																												
		User Input - Button State	Anemometer Input - Calibrate	Anemometer Input - Direction	Anemometer Input - RPM	Accelerometer Input - Accelerometer Reading	Get Data - Get Processed State	Display Output - Format Data	Display Output - Print	Verify Data - Verify Accelerometer	Verify Data - Verify Anemometer	Encapsulate Data - Encapsulate Wind Data	Process Data - Calculate Wind Speed	Process Data - Calculate Wind Direction	Process Data - Table Lookup	Set Data - Set Wind Speed	Set Data - Set Wind Direction	Set Data - Set Flight Data	Get Data - Get Flight Data	Send Receive - Pack Data	Send Receive - Unpack Data	Send Receive - Send Flight Data	From RRM	Send Receive - ACK	Get Data - Get Wind Data	Hardware Processing - Rotate Pan Servo	Hardware Processing - Rotate Tilt Servo
Producer	User Input - Button State							D1																						
	Anemometer Input - Calibrate			D6																										
	Anemometer Input - Direction							D5			D2																			
	Anemometer Input - RPM										D3																			
	Accelerometer Input - Accelerometer Reading									D4																				
	Get Data - Get Processed State							UI1,UI2,UI3,UI4																						
	Display Output - Format Data								UI5																					
	Display Output - Print																													
	Verify Data - Verify Accelerometer											DP1																		
	Verify Data - Verify Anemometer											DP2,DP3																		
	Encapsulate Data - Encapsulate Wind Data	D19											DP4	DP5																
	Process Data - Calculate Wind Speed														DP6	DP8														
	Process Data - Calculate Wind Direction														DP7		DP9													
	Process Data - Table Lookup																	DP10,DP11												
	Set Data - Set Wind Speed						DP16																							
	Set Data - Set Wind Direction						DP15																		DP18					
	Set Data - Set Flight Data						DP13,DP14												DP12						DP17					
	Get Data - Get Flight Data																			N1										
	Send Receive - Pack Data																					N2								
	Send Receive - Unpack Data																						N5	N4						
	Send Receive - Send Flight Data																													
	From RRM																				N3									
	Send Receive - ACK							N6																						
	Get Data - Get Wind Data																												H1	H2
	Hardware Processing - Rotate Pan Servo																													
	Hardware Processing - Rotate Tilt Servo																													

TABLE 2.2- IRBS PRODUCER CONSUMER MATRIX

2.4.3 - **Module Descriptions**

2.4.3.1 - User Input – Button State

The purpose of the Button State module in the User Input subsystem is to determine the position of all the buttons and switches. All of the buttons and switches will be connected to digital pins on the Arduino Mega.

2.4.3.2 - Anemometer Input – Calibrate

The purpose of the calibrate module in the Anemometer Input Subsystem is to calibrate the anemometer before its first use. The wind vane direction can be permanently calibrated upon startup of the Arduino board by orienting the vane towards the true north during power up. From that moment on, the position of the potentiometer is stored in EEPROM and readouts will be correct. The position of the potentiometer is saved as an integer.

2.4.3.3 - Anemometer Input – Direction

The Purpose of the direction module is to get the digital value from the Anemometer connected to an analog pin and convert it to a usable data type. The initial data type will be stored as an integer value. This integer value represents the 360 degrees of the compass baring.

2.4.3.4 - Anemometer Input – RPM

The Purpose of the RPM module in the Anemometer subsystem is to gather the rotation per minute of the anemometer and convert the raw digital data and convert it into an unsigned long data type to be used later in the program. The long data type will represent the speed in Kilometers per hour and then converted to miles per hour.

2.4.3.5 - Accelerometer Input - Accelerometer Reading

The purpose of the Accelerometer Reading module in the Accelerometer Input subsystem is to gather the raw digital data from the attached accelerometer and convert it into 3 separate integer value. These three values will represent the X,Y, and Z coordinates.

2.4.3.6 - Get Data – Get Processed State

The purpose of the Get Processed State module in the Get Data subsystem is to get the processed wind data and make it available to the Format Data module of the Display Output Subsystem.

2.4.3.7 - Display Output – Format Data

The purpose of the Format Data subsystem in the Display Output subsystem is to get the processed wind data from the Get Processed State module. It formats the data, so that it can be send to the Print module for display. This module also gets the different states of the switches and button from the Button State module. It also gets the acknowledgement from the Set ACK module to check whether the data has been transferred successfully to the RRM.

2.4.3.8 - Display Output - Print

The purpose of the Print module is to display the relevant information to the user. It displays the different modes of the system through the LCD and LEDs, and it also displays the wind speed, wind direction, altitude, and pad angle on an LCD.

2.4.3.9 - Verify Data – Verify Accelerometer

Data that is received from the Accelerometer Reading module in the Data Input layer will be brought to this module for verification. Verification includes filtering out extreme outliers. Extreme outliers are defined as values that exceed the realistic value for a given calculation, in this case any orientation value where value < 0 or value > 360.

2.4.3.10 - Verify Data – Verify Anemometer

Data that is received from the RPM and Direction module in the Data Input layer will be brought to this module for verification. Verification includes filtering out extreme outliers. Extreme outliers are defines as values that exceed the realistic value for a given calculation, in this case wind speed values > 20 or < 0, or direction < 0 or > 360 degrees.

2.4.3.11 - Encapsulate Data – Encapsulate Wind Data

Data that is received from the verify functions will be consolidated into two separate data structures within this module. The flow of information from the verify functions is constant for the duration of the preparation mode. Once the preparation mode is complete the function will call the calculate wind and speed functions for further processing.

2.4.3.12 - Process Data – Calculate Wind Speed

The sole purpose of this function is to average each element of the array of wind speeds.

2.4.3.13 - Process Data – Calculate Wind Direction

The sole purpose of this function is to average each element of the array of wind directions.

2.4.3.14 - Process Data – Table Lookup

Our system is going to have a set of tables that list all the possible settings for a given wind speed and direction. These settings include the pad angle and the rockets turn altitude. Once the averages are calculated this module will conduct the lookup for these two values and send that data to the Set Flight Data module within the Set Data subsystem.

2.4.3.15 - Set Data – Set Wind Speed

This function is simply the interface into the data that the Data Processing layer computes for all other layers. It specifically contains the accessor functions for the average wind speed. Doing this ensures encapsulation of data.

2.4.3.16 - Set Data – Set Wind Direction

This function is simply the interface into the data that the Data Processing layer computes for all other layers. It specifically contains the accessor functions for the average wind direction. Doing this ensures encapsulation of data.

2.4.3.17 - Set Data – Set Flight Data

This function is simply the interface into the data that the Data Processing layer computes for all other layers. It specifically contains the accessor functions for the SD-12 Rocket turn altitude and IRBS pad angle. Doing this ensures encapsulation of data.

2.4.3.18 - Get Data – Get Wind Data

Get Wind Data module serves as a temporary storage for the wind data received from the Set Flight Data and Set Wind Direction modules of the Set Data Layer. These data received are used for the tilting and rotating the servo in a specific direction and angle.

2.4.3.19 - Hardware Processing – Rotate Pan Servo

The module will use the average wind direction to regulate and rotate the servo to a required angle.

2.4.3.20 - Hardware Processing – Rotate Tilt Servo

The purpose of the module is to use the wind speed data to regulate and rotate the servo to a specific angle.

2.4.3.21 - Get Data – Get Flight Data

The Get Flight Data module is responsible for using the altitude to turn the angle that will be used by the rocket.

2.4.3.22 - Send/Receive – Pack Data

The module breaks down the flight data into packets that will be sent to the RRM system

2.4.3.23 - Send/Receive – Unpack Data

The Unpack Data module extracts the signal in Boolean form and stores in Set ACK module

2.4.3.24 - Send/Receive – Send Flight Data

The purpose of the module is to store the packet data and the Boolean value to confirm whether the data is sent or not.

2.4.3.25 - Send/Receive – Set ACK

The Set ACK module stores the Boolean value that gives the result to whether the data is sent or not.

2.5 - RRM Module Decomposition

2.5.1 - Overview

The main purpose of DDS was to break down each sub system into modules. This section contains the high level definition of each module that we have in the RRM system.

2.5.2 - **Module Chart**

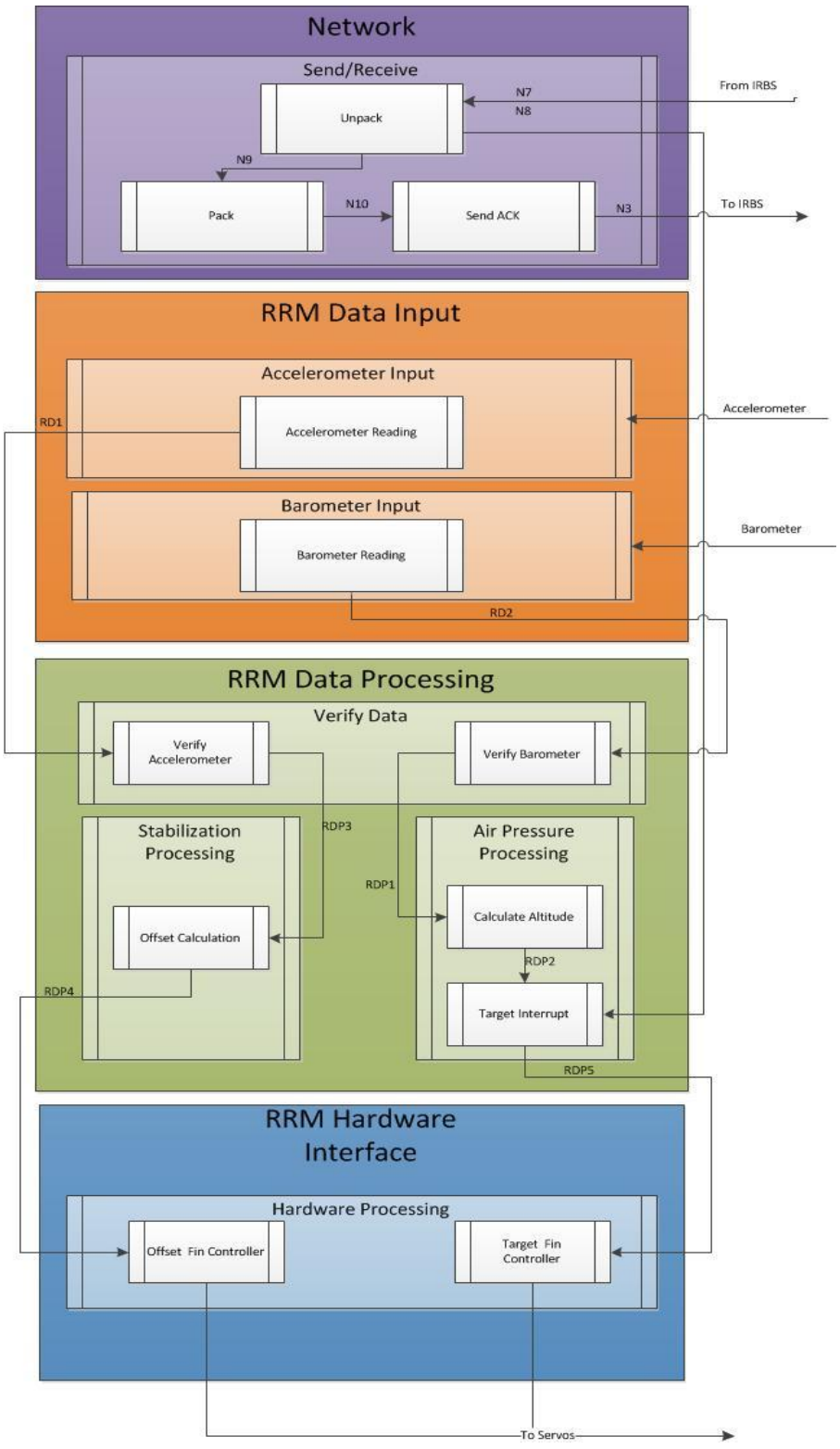

FIGURE 2-3 - RRM MODULE CHART

Data Element	Data Description
N7	A struct that contains an integer that contains the rocket turn altitude.
N8	An integer that contains the rocket turn altitude.
N9	A boolean value that determine whether the data is sent or not
N10	A struct containing a the boolean value
N3	A struct containing a the boolean value
RD1	Integer values that contain the orientation values for x, y, z in degrees.
RD2	An integer value that contains the air pressure in hPa.
RDP1	An integer value that contains the air pressure that has been error checked.
RDP2	An integer that contains the current altitude
RDP3	Integer values that contains the orientation values for x, y, z and has been error checked.
RDP4	Integer values that contain the desired orientation values for x, y, z. This is the minimum orientation that the rocket should be flying.
RDP5	A boolean value that will trigger the turn when the target altitude is hit.

TABLE 2.3- RRM MODULE DATA FLOWS

		Consumer													
		From IRBS	Send Receive - Pack Data	Send Receive - Unpack Data	Send Receive - Send ACK	To IRBS	Accelerometer Input - Accelerometer Reading	Barometer Input - Barometer Reading	Verify Data - Verify Accelerometer	Verify Data - Verify Barometer	Stabilization Processing - Offset Calculation	Air Pressure Processing- Calculate Altitude	Air Pressure Processing - Target Interrupt	Hardware Processing - Offset Fin Controller	Hardware Processing - Target Fin Controller
Producer	From IRBS		N7												
	Send Receive - Pack Data					N10									
	Send Receive - Unpack Data		N9										N8		
	Send Receive - Send ACK					N3									
	To IRBS														
	Accelerometer Input - Accelerometer Reading								RD1						
	Barometer Input - Barometer Reading									RD2					
	Verify Data - Verify Accelerometer										RDP3				
	Verify Data - Verify Barometer											RDP1		RDP4	
	Stabilization Processing - Offset Calculation														
	Air Pressure Processing- Calculate Altitude												RDP2		
	Air Pressure Processing - Target Interrupt														RDP5
	Hardware Processing - Offset Fin Controller														
	Hardware Processing - Target Fin Controller														

TABLE 2.4- RRM PRODUCER CONSUMER MATRIX

2.5.3 - Module Descriptions

2.5.3.1 - Send/Receive – Pack Data

The module receives the packet data and stores it in a structure to be packed and acknowledged.

2.5.3.2 - Send/Receive – Unpack Data

The Pack module extracts the packet in Boolean form to determine if the data is sent or not.

2.5.3.3 - Send/Receive – Send ACK

The Send ACK module receives the Boolean and stores it as a structure object.

2.5.3.4 - Accelerometer Input - Accelerometer Reading

The purpose of the Accelerometer Reading module in the Accelerometer Input subsystem is to gather the raw digital data from the attached accelerometer and convert it into 3 separate integer value. These three values will represent the X,Y, and Z coordinates.

2.5.3.5 - Barometer Input - Barometer Reading

The purpose of the Barometer Reading module in the Barometer Input subsystem is to gather the raw digital data from the BMP085 Barometric Pressure Sensor and convert it into an integer value representing the current air pressure.

2.5.3.6 - Verify Data – Verify Accelerometer

Data that is received from the Accelerometer Reading module in the Data Input layer will be brought to this module for verification. Verification includes filtering out extreme outliers. Extreme outliers are defined as values that exceed the realistic value for a given calculation, in this case any orientation value where value < 0 or value > 360.

2.5.3.7 - Verify Data – Verify Barometer

Data that is received from the Barometer Reading module in the Data Input layer will be brought to this module for verification. Verification includes filtering out extreme outliers. Extreme outliers are defined as values that exceed the realistic value for a given calculation, in this case any orientation value where value < 300 or value > 1100.

2.5.3.8 - Stabilization Processing – Offset Calculation

The stabilization of the rocket is happening during the rocket accent until the rocket turns. Given that the F50-6 rocket motor burns for 1.37 seconds this module will be stabilizing the rocket for about a second, which is roughly when it will reach its target turn altitude. Stabilization is defined as correcting the rockets orientation on accent. Corrections may have to be made if the rocket changes its roll orientation. This is critical given that the turn angle and direction of the rocket are fixed.

2.5.3.9 - Air pressure Processing - Calculate Altitude

Given that the SD-12 rocket must know its current altitude so that we know when to turn into the wind we are required to do some conversions from air pressure, hPa, feet above the IRBS. This is required because the turn altitude as prescribed by the lookup tables in the IRBS Data Processing Layer were calculated using feet above the IRBS.

2.5.3.1 - Air pressure Processing - Target Interrupt

The Target Interrupt module's only purpose is to listen to the altitude readings from the Calculate Altitude module and send the command to turn the rocket when the target altitude is reached.

2.5.3.2 - Hardware Processing – Offset Fin Controller

The module will use the integer x,y,and z coordinates to offset the rocket fins for proper stability.

2.5.3.3 - Hardware Processing – Target Fin Controller

The purpose of the module is to access the coordinate values needed by the fin and triggers the turning of the servo using the Boolean value

3. - IRBS Data Input

3.1 - Overview

The IRBS Data Input Layer is used for handling the user input, the anemometer input, and the accelerometer input. The layer's primary reasonability is converting the raw digital signal into certain usable data types. The conversion of the data will take place in the Arduino Mega. The IRBS Data Input layer consists of three subsystems, the User Input, the Anemometer Input, and the Accelerometer Input.

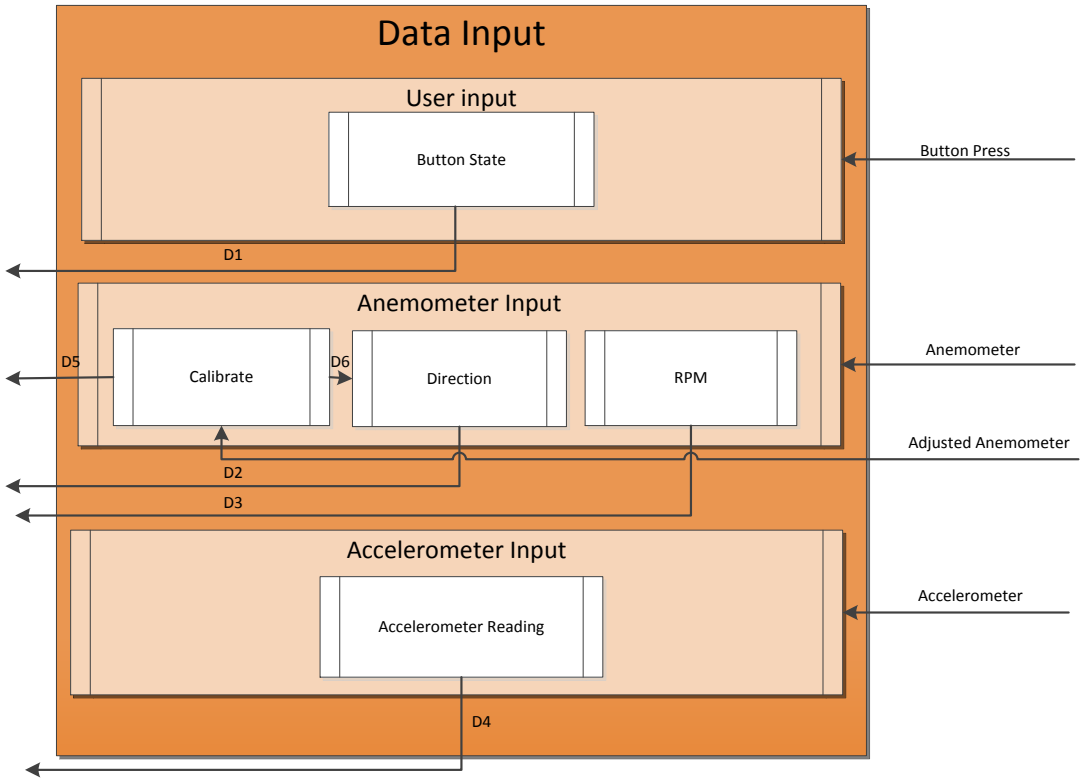

FIGURE 3-1- DATA INPUT DIAGRAM

3.2 - User Input – Button State

3.2.1 - Prologue

The purpose of the Button State module in the User Input subsystem is to determine the position of all the buttons and switches. All of the buttons and switches will be connected to digital pins on the Arduino Mega.

3.2.2 – **Interfaces**

All the buttons and switches will interface though the digital pins on the Arduino Mega.

3.2.3 – **External Data Dependencies**

The button state module is dependent on the actual button presses and switch movement from the user of the system. It is also dependent on the encapsulate data module to get the pad angle data.

3.2.4 – **Internal Data Dependencies**

The module is dependent on the Boolean value from the encapsulate data module.

3.2.5 – **Process/Pseudocode**

```
const int switch1 = 2;                    // the number of the first switch pin
const int switch2 = 3;                    // the number of the second switch pin
const int switch3 = 4;                    // the number of the third switch pin
const int launchButton = 5;     // the number of the launch button pin


// variables will change:
int switchState1 = 0;         // variable for reading the switch1 status
int switchState2 = 0;         // variable for reading the switch2 status
int switchState3 = 0;         // variable for reading the switch3 status
int launchButtonState = 0;         // variable for reading the launchButton status

void setup() {

  // initialize the pushbutton pin as an input:
  pinMode(switch1, INPUT);
  pinMode(switch2, INPUT);
  pinMode(switch3, INPUT);
  pinMode(launchButton, INPUT);
}

void loop(){
  // read the state of the pushbutton value:
  switchState1 = digitalRead(switch1);
  switchState2 = digitalRead(switch2);
  switchState3 = digitalRead(switch3);
  launchButtonState = digitalRead(launchButton);

  // check if the pushbutton is pressed if it is, the buttonState is HIGH:

  if ((switchState1 == HIGH) && (switchState2 == LOW) && (switchState2 ==LOW))
  {
       //User is in setup mode
  }

  if ((switchState1 == HIGH) && (switchState2 == HIGH) && (switchState2 ==LOW))
  {
       //User is in preperation mode
       //Wait 2 minutes to gather data
  }
       //if user waited two minutes
```

```
  if ((switchState1 == HIGH) && (switchState2 == HIGH) && (switchState2 ==HIGH))
{
     //User is in launch mode
     //display count down
     //After count down
     if ((switchState1 == HIGH) && (switchState2 == HIGH) && (switchState2
     ==HIGH) && (launchButtonState == HIGH))
     {
            If (Object.getPadTilt==1)
            {
            //Launch Rocket
            }
     }
}

}
```

3.3 - Anemometer Input – Calibrate

3.3.1 - Prologue

The purpose of the calibrate module in the Anemometer Input Subsystem is to calibrate the anemometer before its first use. The wind vane direction can be permanently calibrated upon startup of the ARDUINO board by orienting the vane towards the true north during power up. From that moment on, the position of the potentiometer is stored in EEPROM and readouts will be correct. The position of the potentiometer is saved as an integer.

3.3.2 - Interfaces

The Davis Anemometer (#7911) interfaces with the Arduino Mega on one digital pin and one analog pin. The Arduino Mega's EEPROM (nonvolatile memory) is also accessed and the potentiometer position is saved to the EEPORM.

3.3.3 - External Data Dependencies

The module is only dependent on the physical direction of the anemometer during power up.

3.3.4 - Internal Data Dependencies

The module will send data to both the format data module in the user interface layer as well as the RPM module in the data input layer.

3.3.5 - Process/Pseudocode

```
#define PotPin (A0)    // define the input pin for the wind vane potentiometer
#define CalPin (A1)    // define the input pin to initiate direction calibration @
startup. Ground pin to calibrate
void calibrate () {
int PotValue = 0;      // variable to store the value coming from the
potentiometer
int DirCorr = 0;       // Correction on direction ( - 360  to + 360)
byte DirCorrB1 = 0;    // 2 bytes of DirCorr
byte DirCorrB2 = 0;
lcd.print("Now calibrating ...    ");
delay (1000);  //Wait 1 second
```

```
PotValue = analogRead(PotPin);     // read the value from the potentiometer
DirCorr = map(PotValue, 0, 1023, 359, 0);

 lcd.setCursor(0, 1);
lcd.print("CAL value = ");
lcd.print(DirCorr, DEC);
lcd.print("            ");
delay (2000);  //Wait 2 seconds
DirCorrB1 = DirCorr / 255;
 if (DirCorrB1 == 1)
{
DirCorrB1 = 255;
DirCorrB2 = DirCorr - 255 ;
}
else {
DirCorrB1 = DirCorr;
DirCorrB2 = 0;
  }
 EEPROM.write (1, DirCorrB1);
 EEPROM.write (2, DirCorrB2);
wait:
 lcd.setCursor(0, 1);
lcd.print("CAL OK ");
if ((analogRead(CalPin)<512)) goto wait;
lcd.setCursor(0, 1);
lcd.print("Now rebooting...    ");
delay (1000);
setup ();
}
```

3.4 - Anemometer Input – Direction

3.4.1 - Prologue

The Purpose of the direction module is to get the digital value from the Anemometer connected to an analog pin and convert it to a usable data type. The initial data type will be stored as an integer value. This integer value represents the 360 degrees of the compass baring.

3.4.2 - Interfaces

The Davis Anemometer (#7911) interfaces with an Arduino Mega analog pin for the wind direction data.

3.4.3 - External Data Dependencies

The direction module is dependent on the actual external wind direction.

3.4.4 - Internal Data Dependencies

The direction module is not dependent on any internal data.

3.4.5 - Process/Pseudocode

```
int windDirection()
{
```

```
  int Direction ; // Wind direction
  int PotValue  = analogRead(PotPin);     // read the value from the potmeter
  Direction = map(PotValue, 0, 1023, 0, 359);
  Direction = Direction + DirCorr + 3;   // Correct for offset & 5° precision
 convert:       // Convert to 360°
  if (Direction < 0)
{
    Direction = Direction + 360;
    goto convert;
  }
  if (Direction > 360)
{
    Direction = Direction - 360;
    goto convert;
  }
  if (Direction == 360) Direction = 0;

  return Direction;
  }
```

3.5 - Anemometer Input – RPM

3.5.1 - Prologue

The Purpose of the RPM module in the Anemometer subsystem is to gather the rotation per minute of the anemometer and convert the raw digital data and convert it into an unsigned long data type to be used later in the program. The long data type will represent the speed in Kilometers per hour and then converted to miles per hour.

3.5.2 - Interfaces

The Davis Anemometer (#7911) interfaces with an Arduino Mega digital pin for the wind speed data.

3.5.3 - External Data Dependences

The RPM module is dependent only on the actual external wind speed.

3.5.4 - Internal Data Dependences

The direction module is not dependent on any internal data.

3.5.5 - Process/Pseudocode

```
volatile unsigned long ContactTime; // Timer to avoid contact bounce in interrupt
routine
volatile unsigned long RPMTops;     // RPM tops counter in interrupt routine

 void rpm ()
{

// debounce of REED contact. With 15ms speed more than 150 km/h can be measured
if ((millis() - ContactTime) > 15 )
       {
```

```
        RPMTops++;
         ContactTime = millis();
        }

}

// convert to km/h

if ((RPMTops >= 0) and (RPMTops <= 21)) RPM = RPMTops * 1.2;
if ((RPMTops > 21) and (RPMTops <= 45)) RPM = RPMTops * 1.15;
if ((RPMTops > 45) and (RPMTops <= 90)) RPM = RPMTops * 1.1;
if ((RPMTops > 90) and (RPMTops <= 156)) RPM = RPMTops * 1.0;
if ((RPMTops > 156) and (RPMTops <= 999)) RPM = RPMTops * 1.0;

// convert to mp/h

RPM = RPM* 0.621371192
```

3.6 - Accelerometer Input - Accelerometer Reading

3.6.1 - Prologue

The purpose of the Accelerometer Reading module in the Accelerometer Input subsystem is to gather the raw digital data from the attached accelerometer and convert it into 3 separate integer value. These three values will represent the X,Y, and Z coordinates.

3.6.2 - Interfaces

The ADXL326 - 5V ready triple-axis accelerometer will interface with the Arduino Mega through 3 analog pins.

3.6.3 - External Data Dependences

The Accelerometer Reading module is only dependent on the physical orientation of the launch platform.

3.6.4 - Internal Data Dependences

The Accelerometer Module is not dependent on any internal data.

3.6.5 - Process/Pseudocode

```
const int groundpin = 18;             // analog input pin 4 -- ground
const int powerpin = 19;              // analog input pin 5 -- voltage
const int xpin = A3;                  // x-axis of the accelerometer
const int ypin = A2;                  // y-axis
const int zpin = A1;                  // z-axis (only on 3-axis models)

void setup()
{

  pinMode(groundpin, OUTPUT);
  pinMode(powerpin, OUTPUT);
  digitalWrite(groundpin, LOW);
  digitalWrite(powerpin, HIGH);
  int x;
  int y;
```

```
  int z;
}

void loop()
{
  // get the x sensor values:
  x=analogRead(xpin));
  // get the y sensor values:
  y=analogRead(ypin));
  // get the z sensor values:
  z=analogRead(zpin));

  // delay before next reading:
  delay(100);
}
```

4. - IRBS User Interface

4.1 - Overview

The IRBS User Interface Layer is used for allowing the user to visually interact with the system. This layer's primary responsibility is to get the button presses from the user input and the processed wind data. It then formats the data and displays it on an LCD screen. This layer consists of two subsystems; Get Data and Display Output. Get Data Subsystem consists of one module; Get Processed State. Display Output Subsystem consists of two modules; Format Data and Print.

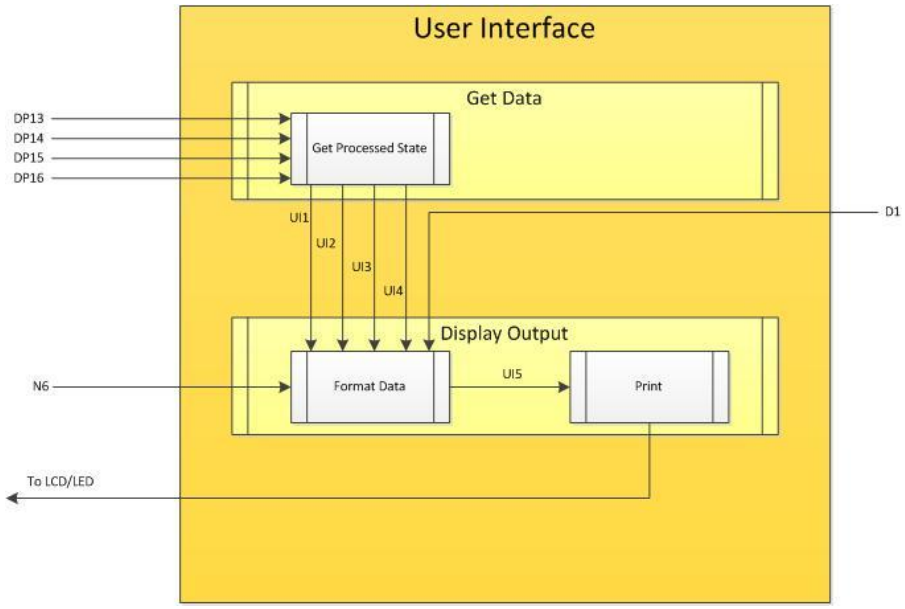

FIGURE 4-1 - USER INTERFACE DIAGRAM

4.2 - Get Data - Get Processed State

4.2.1 - Prologue

The purpose of the Get Processed State module in the Get Data subsystem is to get the processed wind data and make it available to the Format Data module of the Display Output subsystem.

4.2.2 - Interfaces

The Get Processed State interfaces with the Set Wind Speed, Set Wind Direction, and Set Flight Data modules in the Set Data Subsystem of the Data Processing Layer.

4.2.3 - External Data Dependencies

The module is dependent on the Set Wind Speed, Set Wind Direction, and Set Flight Data modules for the wind data. It gets integer value of altitude and float values of pad angle, wind speed and wind direction.

4.2.4 - Internal Data Dependencies

The module is not dependent on any data that is internal.

4.2.5 - Process/Pseudo code

```
void getWindData()
{
	int altitude;
	float w_speed;
	float w_direction;
	float pad_angle;

	altitude = sd.getAlt();     //get the altitude
	w_speed = sd.getSpd();      //get the wind speed
	w_direction = sd.getDir();  //get the wind direction
	pad_angle = sd.getAng();    //get the pad angle
}
```

4.3 - Display Output – Format Data

4.3.1 - Prologue

The purpose of the Format Data subsystem in the Display Output subsystem is to get the processed wind data from the Get Processed State module. It formats the data, so that it can be sent to the Print module for display. This module also gets the different states of the switches and button from the Button State module. It also gets the acknowledgement from the Set ACK module to check whether the data has been transferred successfully to the RRM.

4.3.2 - Interfaces

The Format Data interfaces with the Get Processed State module in the Get Data Subsystem. It also interfaces with the Button State module of the Data Input Layer to get the actual button presses and switch movements. It also interfaces with the Set ACK module of the Send/Receive Subsystem in the Network Layer.

4.3.3 - External Data Dependencies

The module is dependent on the Get Processed State module for the processed wind data and Button State module for the button presses and switch movements. It gets integer value of altitude and float values of pad angle, wind speed and wind direction. It also gets a Boolean value from the set ACK module.

4.3.4 - Internal Data Dependencies

The module is not dependent on any data that is internal.

4.3.5 - Process/Pseudo code

```
//get the button states
int SS1 = 0;               // variable for reading the switch1 status
```

```
int SS2 = 0;                // variable for reading the switch2 status
int SS3 = 0;                // variable for reading the switch3 status
int LBS = 0;               // variable for reading the launch button status

void gbs(ButtonState getState)
{
       SS1 = getState.switchState1();     //switch state for setup mode
       SS2 = getState.switchState2();   //switch state for preparation mode
       SS3 = getState.switchState3();     //switch state for launch mode
       LBS = getState.launchButtonState(); //switch state for actual launch
}

//A Boolean value from the network layer to determine whether the data has been
sent properly to the RRM, if ack is true data has been sent if ack is false data
has not been sent.
bool ack;

ack = data.getack();
```

4.4 - Display Output – Print

The purpose of the Print module is to display the relevant information to the user. It displays the different modes of the system through LCD and LEDs, and it also displays the wind speed, wind direction, altitude, and pad angle on an LCD.

4.4.1 - Interfaces

The module interfaces with the backlight positive LCD 16x2 through six digital pins. The module also interfaces with the LED indicator through one digital pin. It also interfaces with Get Processed State of the Get Data Subsystem.

4.4.2 - External Data Dependencies

The module is not dependent on any data that is external.

4.4.3 - Internal Data Dependencies

The module is dependent on the Format Data module for the string of formatted data.

4.4.4 - Process/Pseudo code

```
#include <LiquidCrystal.h>
// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(31, 33, 35 37, 41, 45);

int ledPin1 = 50;                 // LED connected to digital pin 50 (Green)
int ledPin2 = 52;                 // LED connected to digital pin 52  (Red)
int ledPin3 = 48;                 // LED connected to digital pin 48  (Blue)

void setup()
{
       pinMode(ledPin1, OUTPUT);       // sets the digital pin as output for
standby mode

       pinMode(ledPin2, OUTPUT);      // sets the digital pin as output for
preparation mode
```

```
	pinMode(ledPin3, OUTPUT);	// sets the digital pin as output for launch
mode
}

void loop()
{
	//set up the LCD's number of columns and rows:
	lcd.begin(16, 2);
	lcd.clear();

	//Print the Standby Mode
	if (SS1 == 1)
	{
		lcd.print(" Standby Mode");
		digitalWrite(ledPin1, HIGH);	//set the Green LED on
		delay(10000);
		digitalWrite(ledPin1, LOW);	//set the Green LED off
	}

	//Print the Preparation Mode
	else if(SS1 == 1 && SS2 == 1)
	{
		lcd.clear();
		lcd.setCursor(0, 0);
		lcd.print(" Preparation Mode");


		digitalWrite(ledPin3, HIGH);		//set the Blue LED on

		/*if wind speed is less than 20 miles per hour, print the wind
		speed, direction, altitude,
		and pad angle*/
		if (w_speed < 20.0)
		{
			lcd.clear();
			lcd.setCursor(0, 0);
			//prints the wind speed and direction
			lcd.print("Speed: "); lcd.print(w_speed); lcd.print(" mph");
			lcd.setCursor(0, 1);
			lcd.print("Direction: "); lcd.print(w_direction)

			//prints the pad angle and altitude
			delay(5000);
			lcd.clear();
			lcd.setCursor(0, 0);
			lcd.print("Angle: "); lcd.print(pad_angle);
			lcd.print((char)223); //prints a degree symbol
			lcd.setCursor(0, 1);
			lcd.print("Altitude: "); lcd.print(altitude);

			digitalWrite(ledPin3, LOW);	//set the Blue LED off
		}

		//if wind speed is greater than 20 miles per hour, print wind speed
		and a warning
```

```
                else if (w_speed >= 20.0)
                {
                        lcd.clear();
                        lcd.setCursor(0, 0);
                        lcd.print("Speed: "); lcd.print(w_speed); lcd.print(" mph");
                        lcd.setCursor(0, 1);
                        lcd.print("WARNING WARNING");
                }
        }

        //Print the launch mode
        else if(SS1 == 1 && SS2 == 1 && SS3 == 1)
        {
                lcd.clear();
                lcd.setCursor(0, 0);
                lcd.print(" Launch Mode");

                digitalWrite(ledPin2, HIGH);       //set the Red LED on
                delay(10000);
                digitalWrite(ledPin2, LOW);        //set the Red LED off

                //print whether the data has been successfully transferred to the
                RRM

                if (ack == true)
                {
                        lcd.clear();
                        lcd.setCursor(0, 0);
                        lcd.print("Data Sent?");
                        lcd.setCursor(0, 1);
                        lcd.print("YES");
                        //Start the countdown

                        //abort the countdown if any or all of the switch states are
                        equal to zero.
                }

                else
                {
                        lcd.clear();
                        lcd.setCursor(0, 0);
                        lcd.print("Data Sent?");
                        lcd.setCursor(0, 1);
                        lcd.print("NO");
                }
        }


        //print that the rocket is launched
        else if(LBS == 1)
        {
                lcd.clear();
                lcd.setCursor(0, 0);
                lcd.print("Rocket Launched");
        }
}
```

```
delay(10000);
```

5. - IRBS Data Processing

5.1 - Overview

The data processing layer on the IRBS is built to do all of the processing needed prior to launch. Processing includes: verifying data, calculations for successful flight and operation, and storing it for other systems to feed form. The bulk of the processing will be calculated during the preparation phase of the launch sequence. Calculations include: average wind speed and direction, and turn altitude for the rocket. The data processing layer represents a C++ object with each of the below modules as functions.

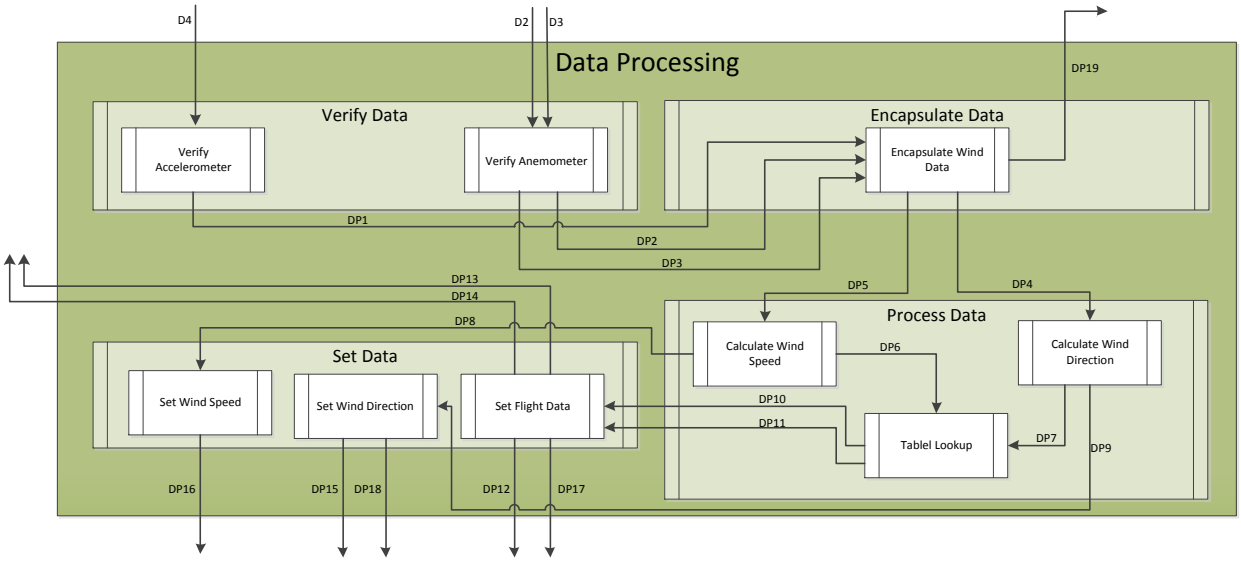

FIGURE 2-1 IRBS DATA PROCESSING DIAGRAM

5.2 - Verify Data – Verify Accelerometer

5.2.1 - Prologue

Data that is received from the Accelerometer Reading module in the Data Input layer will be brought to this module for verification. Verification includes filtering out extreme outliers. Extreme outliers are defined as values that exceed the realistic value for a given calculation, in this case any orientation value where value < 0 or value > 360.

5.2.2 - Interfaces

The Verify Accelerometer module is a function within the Data Processing class. It gets passed values x, y, and z from which we can derive the orientation given that the rocket will be calibrated on the IRBS pad. These calculations are done in the Data Input layer, to clarify this function received values in degrees. Note that this will cancel out acceleration due to gravity from the SD-12 Rockets base frame. This function returns void and calls the function Encapsulate_Data if the values are within the threshold.

5.2.3 - External Data Dependences

None.

5.2.4 - Internal Data Dependences

None.

5.2.5 - Process/Pseudocode

```
//Verifies that the x, y, z values in g forces are not < -16 or > 16
 private void Verify_Accelerometer(int x, int y, int z)
 {
     //If any of the three are out of bounds throw out all three
     if ((x > 0 || x < 360) || (y > 0 || y < 360) || (z > 0 || z < 360))
         Encapsulate_Data(x, y, z);
 }
```

5.3 - Verify Data – Verify Anemometer

5.3.1 - Prologue

Data that is received from the RPM and Direction module in the Data Input layer will be brought to this module for verification. Verification includes filtering out extreme outliers. Extreme outliers are defines as values that exceed the realistic value for a given calculation, in this case wind speed values > 20 or < 0, or direction < 0 or > 360 degrees.

5.3.2 - Interfaces

The Verify Data module is a function within the Data Processing class. It gets passed values wind speed and direction. This function returns void and calls the function Encapsulate_Data if the values are within the threshold.

5.3.3 - External Data Dependences

None.

5.3.4 - Internal Data Dependences

None.

5.3.5 - Process/Pseudocode

```
//Verifies that the speed, and direction values are within the threshold as
//defined below
 private void Verify_Accelerometer(float speed, int direction)
 {
     //If any of the three are out of bounds throw out both
     if ((speed > 0 || speed < 20) || (direction > 360 || direction < 0))
         Encapsulate_Data(speed, direction);
 }
```

5.4 - Encapsulate Data – Encapsulate Wind Data

5.4.1 - **Prologue**

Data that is received from the verify functions will be consolidated into two separate data structures within this module. The flow of information from the verify functions is constant for the duration of the preparation mode. Once the preparation mode is complete the function will call the calculate wind and speed functions for further processing.

5.4.2 - **Interfaces**

The Encapsulate Wind Data is a function within the Data Processing class. It is called from the verify functions and receives the gravitational forces (x, y, z), and wind speed and direction. The accelerometer information is used to determine if the IRBS has taken an angle beyond +- 30 degrees on the x axis. If the pad has exceeded that limit essentially it has fallen over and launch is not possible. This is a failsafe for personal safety reasons. This is ensured by sending a boolean value to the Button State module within the Data input layer. The speed and direction will be encapsulated into two separate arrays which the calculate functions will receive at the end of the preparation phase or when the array is completely filled which we define by acquiring 10000 values.

5.4.3 - **External Data Dependences**

None.

5.4.4 - **Internal Data Dependences**

None.

5.4.5 - **Process/Pseudocode**

```
//Encapsulates the and 3 axis directional information and sends boolean value to
//determine if the x
//has exceeded 30 degrees
//Button Press within the Data Input layer will look at the Data Processing
//object -> Launch variable
//to check if the IRBS is within its tilt threshold, if not is has fallen over.
 private void Enpasulate_Data(int x, int y, int z)
 {
     //sets the local variable Launch to 1 which allows a launch.
     if (x > -30 || x < 30)
     {
         Launch = 1;
         tipOver[tipOver.Length + 1] = x;
     }
     else
         Launch = 0;  //disalows launch
 }

 private void Encapsulate_Data(long speed, int direction)
 {
     speed[speed.Length + 1] = speed;
     direction[direction.Length + 1] = direction;

     if (speed.Length >= 10000)
         Calculate_Wind_Average(speedArray);
```

```
        if (direction.Length >= 10000)
            Calculate_Direction_Average(directionArray);
    }
```

5.5 - Process Data – Calculate Wind Speed

5.5.1 - Prologue

The sole purpose of this function is to average each element of the array of wind speeds.

5.5.2 - Interfaces

The array of wind speed values that is received from the Encapsulate Data function will be averaged in this function after which it will be passed to the Table Lookup function. The resulting calculation is stored as a part of the objects private member data for the rest of the system to access.

5.5.3 - External Data Dependences

None.

5.5.4 - Internal Data Dependences

None.

5.5.5 - Process/Pseudocode

```
private void Average_Speed(long[] speed)
{
    long total = 0;

    foreach(long s in speed)
    {
        total += s;
    }

    averageSpeed = total/10000;
}
```

5.6 - Process Data – Calculate Wind Direction

5.6.1 - Prologue

The sole purpose of this function is to average each element of the array of wind directions.

5.6.2 - Interfaces

The array of direction values that is received from the Encapsulate Data function will be averaged in this function after which it will be passed to the Table Lookup function. The resulting calculation is stored as a part of the objects private member data for the rest of the system to access.

5.6.3 - External Data Dependences

None.

5.6.4 - Internal Data Dependences

None.

5.6.5 - Process/Pseudocode

```
private void Average_Direction(int[] direction)
{
    long total = 0;

    foreach(long d in direction)
    {
        total += d;
    }

    averageDirection = total/10000;
}
```

5.7 - Process Data – Table Lookup

5.7.1 - Prologue

Our system is going to have a set of tables that list all the possible settings for a given wind speed and direction. These settings include the pad angle and the rockets turn altitude. Once the averages are calculated this module will conduct the lookup for these two values and send that data to the Set Flight Data module within the Set Data subsystem.

5.7.2 - Interfaces

The Table Lookup function will get two values, the average wind speed. It will then check the tables that give the SD-Rocket turn altitude and rocket pad angle given the average wind speed. These values will be stored for the rest of the system to use. The resulting calculation is stored as a part of the objects private member data for the rest of the system to access.

5.7.3 - External Data Dependences

None.

5.7.4 - Internal Data Dependences

None.

5.7.5 - Process/Pseudocode

```
private void Table_Lookup()
{
    for(int i = 0; i < table.Length; i++)
        if (table[i][0] == averageSpeed)
            padAngle = table[i][1];
}
```

5.8 - Set Data – Set Wind Speed

5.8.1 - Prologue

This function is simply the interface into the data that the Data Processing layer computes for all other layers. It specifically contains the accessor functions for the average wind speed. Doing this ensures encapsulation of data.

5.8.2 - Interfaces

Accessor function that return the average wind speed for any module that requests it.

5.8.3 - External Data Dependences

None.

5.8.4 - Internal Data Dependences

None.

5.8.5 - Process/Pseudocode

```
public long getSpd()
{
    return averageSpeed;
}
```

5.9 - Set Data – Set Wind Direction

5.9.1 - Prologue

This function is simply the interface into the data that the Data Processing layer computes for all other layers. It specifically contains the accessor functions for the average wind direction. Doing this ensures encapsulation of data.

5.9.2 - Interfaces

Accessor function that return the average wind direction for any module that requests it.

5.9.3 - External Data Dependences

None.

5.9.4 - Internal Data Dependences

None.

5.9.5 - Process/Pseudocode

```
public long getDir()
{
    return averageSpeed;
}
```

5.10 - Set Data – Set Flight Data

5.10.1 - Prologue

This function is simply the interface into the data that the Data Processing layer computes for all other layers. It specifically contains the accessor functions for the SD-12 Rocket turn altitude and IRBS pad angle. Doing this ensures encapsulation of data.

5.10.2 - Interfaces

Accessor function that return SD-12 Rocket turn altitude and IRBS pad angle for any module that requests it.

5.10.3 - External Data Dependences

None.

5.10.4 - Internal Data Dependences

None.

5.10.5 - Process/Pseudocode

```
public long getAlt()
{
    return averageSpeed;
}

public long getAng()
{
    return averageSpeed;
}
```

6. - IRBS Hardware Interface

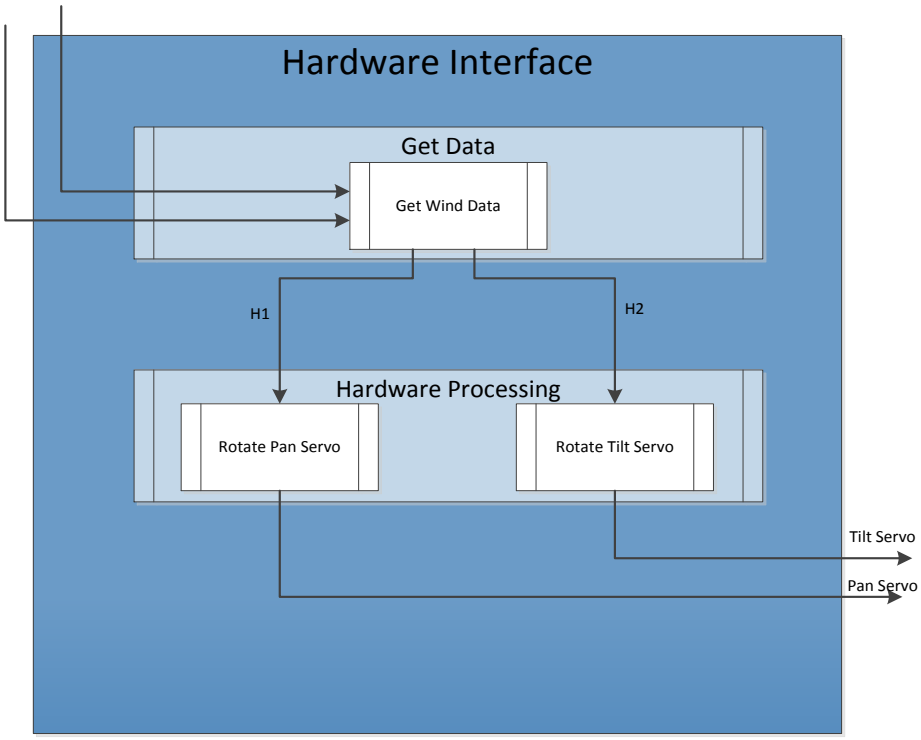

FIGURE 6-1- HARDWARE INTERFACE DIAGRAM

6.1 - Overview

The IRBS Hardware Interface layer is a layer that depends on the Data Processing Layer and consists of two subsystems namely Get Data and Hardware Process subsystems. The layer primary function is to obtain the data that will be used by the servo to rotate at a specific angle and direction depending on the speed of the wind.

6.2 - Get Data – Get Wind Data

6.2.1 - Prologue

Get Wind Data module serves as a temporary storage for the wind data received from the Set Flight Data and Set Wind Direction modules of the Set Data Layer. These data received are used for the tilting and rotating the servo in a specific direction and angle.

6.2.2 - Interfaces

The module only interface with the wind data modules from the Set Data Layer.

6.2.3 - External Data Dependencies

No external data

6.2.4 - Internal Data Dependencies

The module depends on the wind speed data

6.2.5 - Process/Pseudo code

```
public void getWindData(){

float windDir, angPad;

windDir = wd.getDir();

angPad  = wd.getAng();

}
```

6.3 - Hardware Processing – Rotate Pan Servo

6.3.1 - Prologue

The module will use the average wind direction to regulate and rotate the servo to a required angle.

6.3.2 - Interfaces

Rotate Pan Servo module interface with the Get Wind Data module

6.3.3 - External Data Dependencies

No external data

6.3.4 - Internal Data Dependencies

The module depends on the wind speed data

6.3.5 - Process/Pseudo code

```
//This is the objects for tilt servo.
Servo servoTilt;
void setup(){
servoTilt.attach(2);  //The Tilt servo is attached to pin 2.
servoTilt.write(x);  //Initially put the servos at angle not more than
                       30 degress.
}
```

6.4 - Hardware Processing – Rotate Tilt Servo

6.4.1 - Prologue

The purpose of the module is to use the wind speed data to regulate and rotate the servo to a specific angle.

6.4.2 - Interfaces

The module interface with Get Wind Data module

6.4.3 - External Data Dependencies

No external data

6.4.4 - Internal Data Dependencies

Wind direction data

6.4.5 - Process/Pseudo code

```
//This is the objects for pan servo.
Servo servoPan;
void setup(){
servoPan.attach(3);    //The Pan servo is attached to pin 3.
servoPan.write(x);     //Initially put the servos at angle not more
                         than 30 degress.
 }
```

7. - IRBS Network

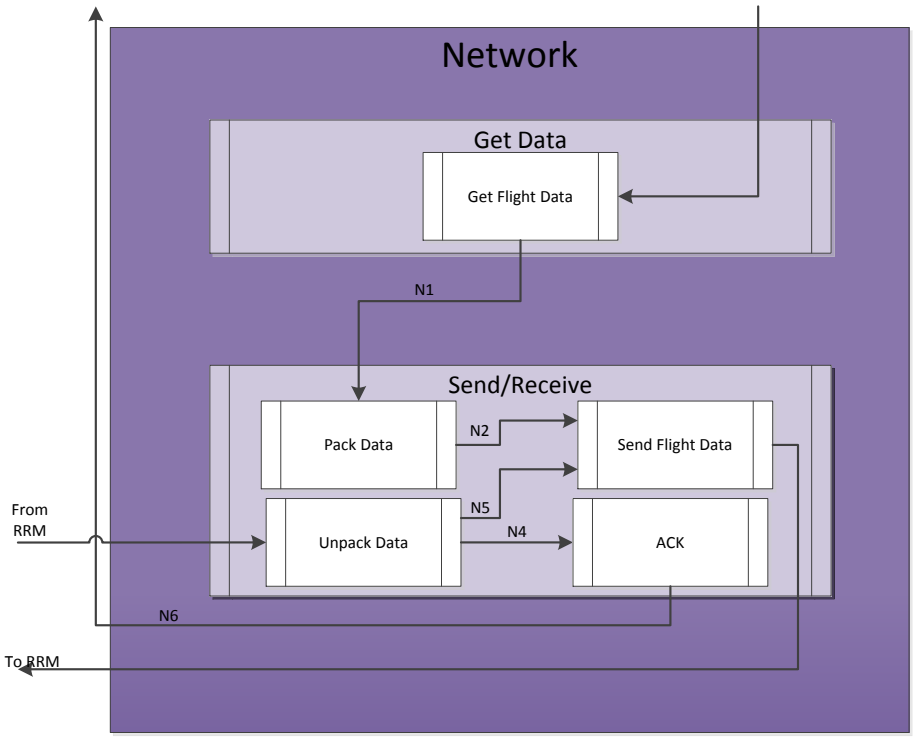

FIGURE 7-1- NETWORK DIAGRAM

7.1 - Overview

The IRBS Network integrates the IRBS system with the RRM system by receiving or sending packets to the RRM Network layer. The layer encodes/decodes packets receive from the Data Process layer to the RRM Network layer.

7.2 - Get Data – Get Flight Data

7.2.1 - Prologue

Get Flight Data module is responsible for using the altitude to turn the angle that will be used by the rocket.

7.2.2 - Interfaces

The module only interface with the Set Flight Data module

7.2.3 - External Data Dependencies

No external data

7.2.4 - Internal Data Dependencies

The module depends on the altitude data stored In the Set Flight Data module

7.2.5 – Process/Pseudo code

```
public void getFlightData(){
int windAlt;
windAlt = fd.getAlt();
}
```

7.3 - Send/Receive – Pack Data

7.3.1 – Prologue

The module breaks down the flight data into packets that will be sent to the RRM system

7.3.2 – Interfaces

It interfaces with the Get Flight Data module

7.3.3 – External Data Dependencies

No external data

7.3.4 – Internal Data Dependencies

Depends on flight data

7.3.5 – Process/Pseudo code

```
Struct A {
    int windAlt;
 }a;
```

7.4 - Send/Receive – Unpack Data

7.4.1 – Prologue

The Unpack Data module extracts the signal in Boolean form and stores in Set ACK module

7.4.2 – Interfaces

Interfaces with RRM system, Set Flight module and Set ACK module

7.4.3 – External Data Dependencies

The module depends on the packet signal coming from the RRM system

7.4.4 – Internal Data Dependencies

No internal data

7.4.5 – Process/Pseudo code

```
Struct C {
    Boolean y;
 } c;
```

7.5 - Send/Receive – Send Flight Data

7.5.1 – Prologue

The purpose of the module is to store the packet data and the Boolean value to confirm whether the data is sent or not.

7.5.2 – Interfaces

The module interfaces with the RRM system, Pack Data module, and the Unpack Data module.

7.5.3 – External Data Dependencies

No external

7.5.4 – Internal Data Dependencies

The module depends on packet data from the Pack Data module and Boolean value from the Unpack Data module

7.5.5 – Process/Pseudo code

```
private void sendFlightData(){
Struct B {
    int windAlt;
    Boolean x;

    } b;
```

7.6 - Send/Receive – Set ACK

7.6.1 – Prologue

The Set ACK module stores the Boolean value that gives the result to whether the data is sent or not.

7.6.2 – Interfaces

The module interface with the Format Data module and the Unpack Data module

7.6.3 – External Data Dependencies

No external data

7.6.4 - **Internal Data Dependencies**

Boolean value

7.6.5 - **Process/Pseudo code**

```
    private boolean sendAck(){
        if (true)
        return 1;
        else
        return 0;
}
```

8. - RRM Network

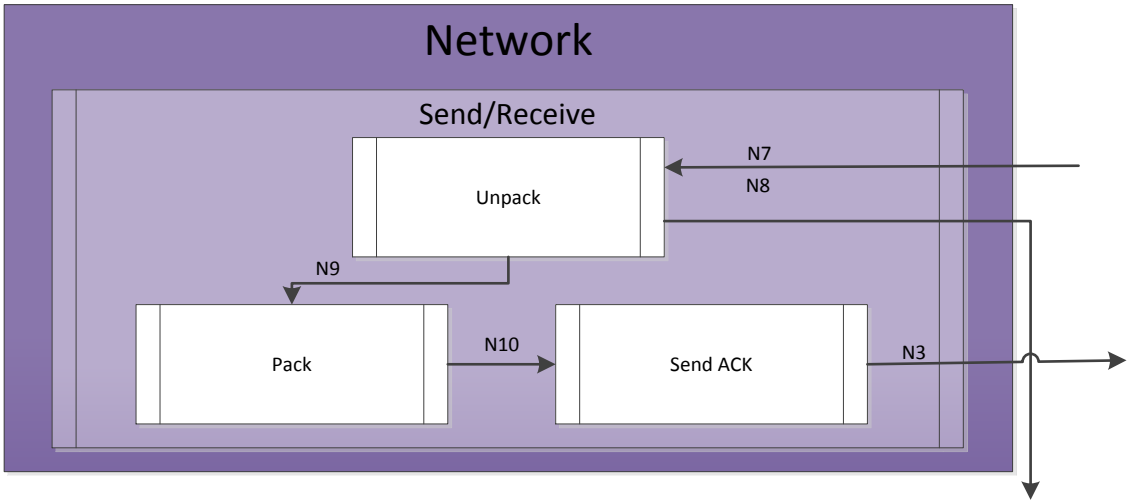

FIGURE 8-1- RRM NETWORK DIAGRAM

8.1 - Overview

The RRM Network integrates the RRM system with the IRBS system by receiving or sending packets to the IRBS Network layer. The layer receives the altitude data from the Set Flight Data module of IRBS Network layer and sends acknowledged signal back.

8.2 - Send/Receive – Unpack

8.2.1 - Prologue

The module receives the packet data and stores it in a structure to be packed and acknowledged.

8.2.2 - Interfaces

It interfaces with the Set Flight Data module of the IRBS system and Pack module

8.2.3 - External Data Dependencies

Altitude data

8.2.4 - Internal Data Dependencies

No internal data

8.2.5 - Process/Pseudo code

```
Struct Alt{
    int altitude;
} alt;
```

8.3 - Send/Receive – Pack

8.3.1 - Prologue

The Pack module extracts the packet in Boolean form to determine if the data is sent or not.

8.3.2 - Interfaces

Interfaces with Unpack module

8.3.3 - External Data Dependencies

No external data

8.3.4 - Internal Data Dependencies

Boolean value

8.3.5 - Process/Pseudo code

```
Struct Bool{
    Boolean x;
} bool;
```

8.4 - Send/Receive – Send ACK

8.4.1 - Prologue

The Send ACK module receives the Boolean and stores it as a structure object.

8.4.2 - Interfaces

The module interfaces with Pack module and the IRBS system

8.4.3 - External Data Dependencies

No external data

8.4.4 - Internal Data Dependencies

Boolean object

8.4.5 - **Process/Pseudo code**

```
private boolean sendAck(){
    If (true)
    return 1;
    else
    return 0;
}
```

9. - RRM Data Input

9.1 - Overview

The RRM Data Input Layer is used the accelerometer input and the barometer input. The layer's primary reasonability is converting the raw digital signal into certain usable data types. The conversion of the data will take place in the Arduino Uno. The RRM Data Input layer consists of two subsystems, the Anemometer Input, and the Barometer Input.

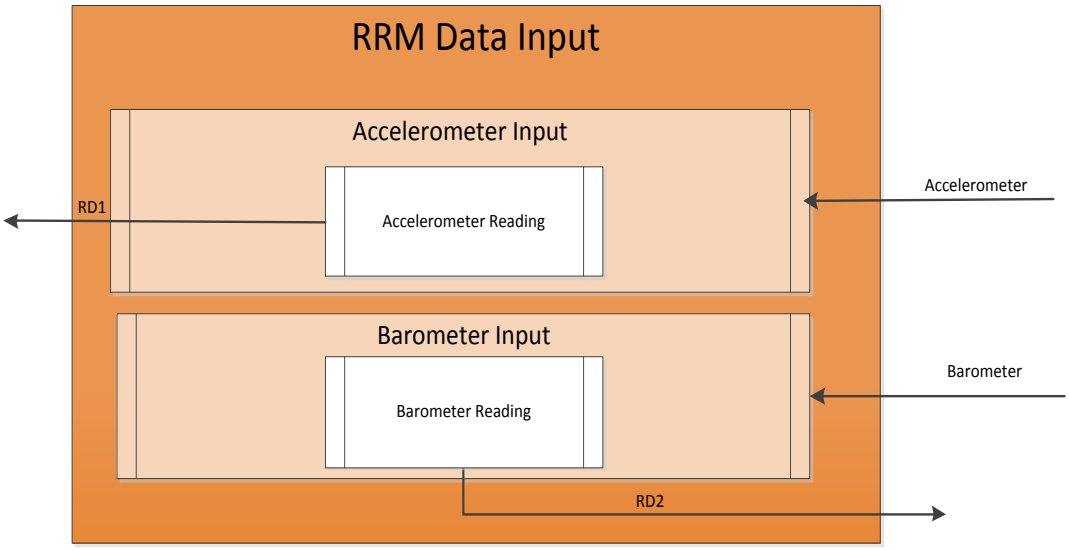

FIGURE 9-1 - RRM DATA INPUT DIAGRAM

9.2 - Accelerometer Input - Accelerometer Reading

9.2.1 - Prologue

The purpose of the Accelerometer Reading module in the Accelerometer Input subsystem is to gather the raw digital data from the attached accelerometer and convert it into 3 separate integer value. These three values will represent the X,Y, and Z coordinates.

9.2.2 - Interfaces

The ADXL326 - 5V ready triple-axis accelerometer will interface with the Arduino Uno through 3 analog pins.

9.2.3 - External Data Dependences

The Accelerometer Reading module is only dependent on the physical orientation of the rocket.

9.2.4 - Internal Data Dependences

The Accelerometer Module is not dependent on any internal data.

9.2.5 - Process/Pseudocode

```
const int groundpin = 18;             // analog input pin 4 -- ground
const int powerpin = 19;              // analog input pin 5 -- voltage
const int xpin = A3;                  // x-axis of the accelerometer
const int ypin = A2;                  // y-axis
const int zpin = A1;                  // z-axis (only on 3-axis models)

void setup()
{

  pinMode(groundpin, OUTPUT);
  pinMode(powerpin, OUTPUT);
  digitalWrite(groundpin, LOW);
  digitalWrite(powerpin, HIGH);
  int x;
  int y;
  int z;
}

void loop()
{
  // get the x sensor values:
  x=analogRead(xpin));
  // get the y sensor values:
  y=analogRead(ypin));
  // get the z sensor values:
  z=analogRead(zpin));

  // delay before next reading:
  delay(100);
}
```

9.3 - Barometer Input - Barometer Reading

9.3.1 - Prologue

The purpose of the Barometer Reading module in the Barometer Input subsystem is to gather the raw digital data from the BMP085 Barometric Pressure Sensor and convert it into an integer value representing the current air pressure.

9.3.2 - Interfaces

The BMP085 Barometric Pressure Sensor will interface with the Arduino Uno through two analog pins.

9.3.3 - External Data Dependences

The Barometer Reading module is only dependent on the current air pressure.

9.3.4 - Internal Data Dependences

The Barometer Reading module is not dependent on any internal data.

9.3.5 – **Process/Pseudocode**

```
#include "Adafruit_BMP085.h"

Adafruit_BMP085 bmp;

void setup()
{
int baroReading;
bmp.begin();
}
void loop() {

    baroReading = bmp.readPressure());

    delay(1);
}
```

10. - RRM Data Processing

10.1 - Overview

The Data Processing layer on the RRM is built to do all of the processing needed during and after launch. Processing includes: verifying data and calculations for successful flight during flight operation. Calculations include: current altitude based on the barometer, and orientation based on the accelerometer. Essentially the RRM Data Processing is the brain of the operation during flight. It will tell the hardware layer when to turn and orientation corrections for stabilization. Once the rocket turns at the target altitude processing has completed and physics takes over. The data processing layer represents a C++ object with each of the below modules as functions.

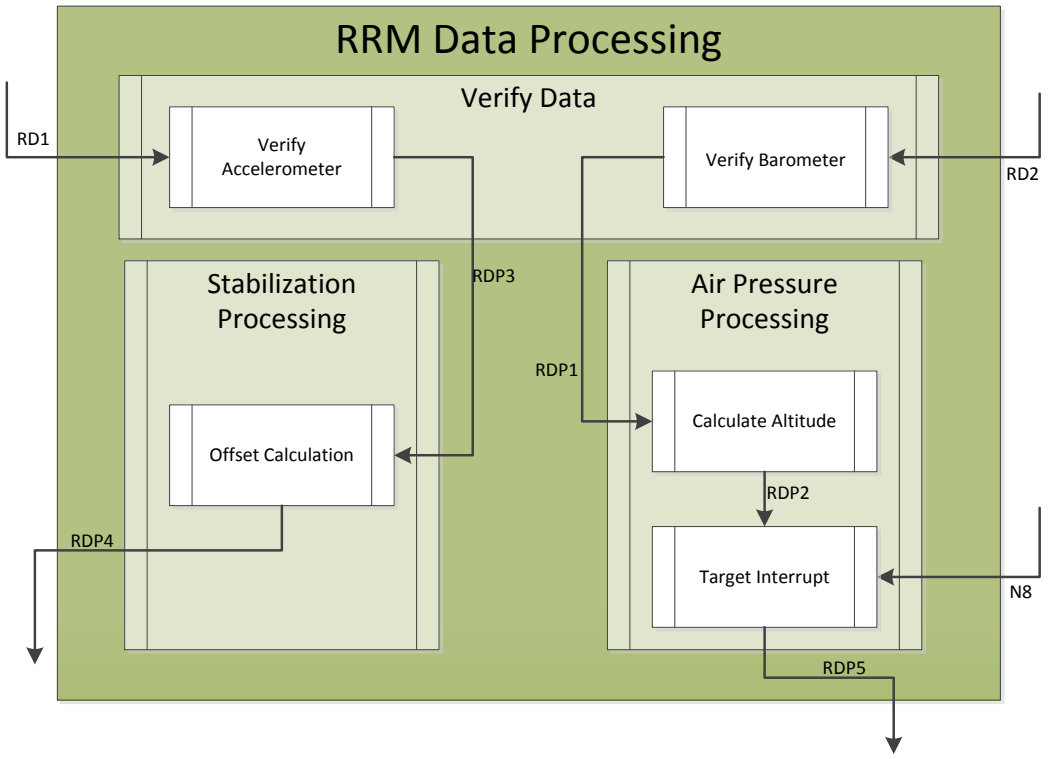

FIGURE 2-1 RRM DATA PROCESSING DIAGRAM

10.2 - Verify Data - Verify Accelerometer

10.2.1 - Prologue

Data that is received from the Accelerometer Reading module in the Data Input layer will be brought to this module for verification. Verification includes filtering out extreme outliers. Extreme outliers are defined as values that exceed the realistic value for a given calculation, in this case any orientation value where value < 0 or value > 360.

10.2.2 - **Interfaces**

The Verify Accelerometer module is a function within the RRM Data Processing class. It gets passed values x, y, and z from which we can derive the orientation given that the rocket will be calibrated on the IRBS pad. These calculations are done in the Data Input layer; to clarify this function received values in degrees. Note that this will cancel out acceleration due to gravity from the SD-12 Rockets base frame. This function returns void and calls the function Offset_Calculation if the values are within the threshold.

10.2.3 - **External Data Dependences**

None.

10.2.4 - **Internal Data Dependences**

Data from the Accelerometer Reading module in the Data Input Layer.

10.2.5 - **Process/Pseudocode**

```
//Verifies that the x, y, z values in g forces are not < -16 or > 16
 private void Verify_Accelerometer(int x, int y, int z)
 {
     //If any of the three are out of bounds throw out all three
     if ((x > 0 || x < 360) || (y > 0 || y < 360) || (z > 0 || z < 360))
         Encapsulate_Data(x, y, z);
 }
```

10.3 - Verify Data - Verify Barometer

10.3.1 - **Prologue**

Data that is received from the Barometer Reading module in the Data Input layer will be brought to this module for verification. Verification includes filtering out extreme outliers. Extreme outliers are defined as values that exceed the realistic value for a given calculation, in this case any orientation value where value < 300 or value > 1100.

10.3.2 - **Interfaces**

The Verify Accelerometer module is a function within the RRM Data Processing class. It gets passed the value of the current air pressure from which we can derive the altitude. These calculations are done in the Calculate Altitude module. The air pressure unit is in hPa or hectopascal which can easily be converted to bar or psi. This function returns void and calls the function Calculate_Altitude if the values are within the threshold.

10.3.3 - **External Data Dependences**

None.

10.3.4 - **Internal Data Dependences**

Data from the Barometer Reading module in the Data Input Layer.

10.3.5 - **Process/Pseudocode**

```
//Verifies that the air pressure values are within the threshold as defined below
private void Vefiry_Barometer()
{
    if (direction > 300 || direction < 1100)
        Calculate_Altitude(int airPressure);
}
```

10.4 - Stabilization Processing - Offset Calculation

10.4.1 - Prologue

The stabilization of the rocket is happening during the rocket accent until the rocket turns. Given that the F50-6 rocket motor burns for 1.37 seconds this module will be stabilizing the rocket for about a second, which is roughly when it will reach its target turn altitude. Stabilization is defined as correcting the rockets orientation on accent. Corrections may have to be made if the rocket changes its roll orientation. This is critical given that the turn angle and direction of the rocket are fixed.

10.4.2 - Interfaces

The stabilization function receives the rockets current orientation in 3 dimensional space from the Verify Accelerometer module. With this information it will know its current orientation and the orientation that it should be facing and thus will be able to make the correction. We are waving the need for a PID controller given that the direction of turn is approximate within +-10 degrees because of obvious weather uncertainties. We will simulate an slightly under dampened system by telling the rocket to orient itself to the minimum threshold of the range and to only correct back if it exceeds the 20 degree bandwidth. Once a correction is decided to be made the desired orientation will be sent to the Offset Fin Controller module in the hardware layer for correction execution.

10.4.3 - External Data Dependences

None.

10.4.4 - Internal Data Dependences

None.

10.4.5 - Process/Pseudocode

```
private void Offset_Calculation(int x, int y, int z)
{
    //desired_x = desired x orinetation
    //desired_y = desired y orinetation
    //desired_z = desired z orinetation

    //if the current orinetation exceeds +- 10 degrees of desired orientation
    if ((x - 10 < desired_x || y - 10 < desired_y || z - 10 < desired_z)
    {
       //call the Offset Fin Controller function and pass the desired orientation
        Offset_Fin(desired_x - 10, desired_y - 10, desired_z - 10);
    }
```

```
    else if (x + 10 > desired_x || y + 10 > desired_y || z + 10 > desired_z)
    {
       //call the Offset Fin Controller function and pass the desired orientation
        Offset_Fin(desired_x + 10, desired_y + 10, desired_z + 10);
    }
}
```

10.5 - Air Pressure Processing - Calculate Altitude

10.5.1 - **Prologue**

Given that the SD-12 rocket must know its current altitude so that we know when to turn into the wind we are required to do some conversions from air pressure, hPa, feet above the IRBS. This is required because the turn altitude as prescribed by the lookup tables in the IRBS Data Processing Layer were calculated using feet above the IRBS.

10.5.2 - **Interfaces**

This function does the conversion from air pressure, hPa, to our altitude unit, feet. It then sends this altitude reading to the Target Interrupt module which will activate the turn process when the desired altitude is achieved.

10.5.3 - **External Data Dependences**

None.

10.5.4 - **Internal Data Dependences**

None.

10.5.5 - **Process/Pseudocode**

```
private void Calculate_Altitude(int airPressure)
{
    int altitude = 0;
    int seaLevel = 101325;
    float a = 0.0;
    int currentTemp;
    float b = 0.0;
    float currentAltitudeMeters = 0.0;
    float currentAltitudeFeet = 0.0;

    //executing formula to convert to feet above sea level
    altitude = airPressure * 100;
    relativePressure = altitude / seaLevel;
    x = ln(relativePressure) * 287.053;
    b = x * ((currentTemp + 459.67) * 5/9);

    //altitude given in meters above sea level
    currentAltitudeMeters = b/-9.8;

    //altitude given in feet
    currentAltitudeFeet = currentAltitudeMeters/.3048;

    Target_Altitude(currentAltitudeFeet);
```

```
}
```

10.6 - Air Pressure Processing - Target Interrupt

10.6.1 - Prologue

The Target Interrupt module's only purpose is to listen to the altitude readings from the Calculate Altitude module and send the command to turn the rocket when the target altitude is reached.

10.6.2 - Interfaces

This function receives the target altitude from the Unpack module in the Network Layer, and the current altitude from the Current Altitude module in the Data Input Layer. Once the current altitude and target altitude match this module will send a bit value to the Target Fin Controller in the Network Layer signaling it to follow it's turn algorithm.

10.6.3 - External Data Dependences

None.

10.6.4 - Internal Data Dependences

The target altitude from Unpack module in the Network Layer

10.6.5 - Process/Pseudocode

```
private void Target_Altitude(float currentAltitudeFeet)
{
    Target_Fin = false;

    if (currentAltitudeFeet >= targetAltitude)
        Target_Fin(true);
}
```

11. - RRM Hardware Interface

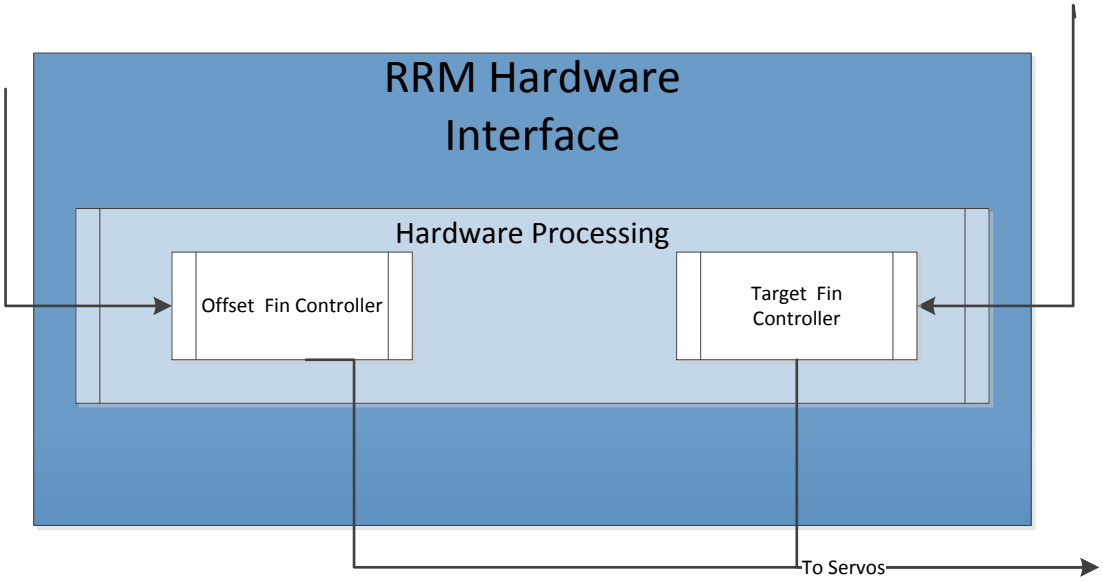

FIGURE 11-1 – RRM HARDWARE INTERFACE DIAGRAM

11.1 - Overview

The RRM Hardware Interface Layer is the last layer of the Rocket Recovery System layers and consists of Hardware Process Subsystem. The subsystem receives data from the RRM Data Process layer by obtaining air pressure and acceleration data in determine the stability of the rocket and the servo opening for the landing.

11.2 - Hardware Processing – Offset Fin Controller

11.2.1 - Prologue

The module will use the integer x,y,and z coordinates to offset the rocket fins for proper stability.

11.2.2 - Interfaces

The module interfaces with the Offset Calculation module and the system servo

11.2.3 - External Data Dependencies

No external data

11.2.4 - Internal Data Dependencies

Integer values x, y, z

11.2.5 - Process/Pseudo code

```
private int offFinCon(){
        int y;
        y= fd.calculate_altitude();
        return y;
}
```

11.3 - Hardware Processing – Target Fin Controller

11.3.1 - Prologue

The purpose of the module is to access the coordinate values needed by the fin and triggers the turning of the servo using the Boolean value.

11.3.2 - Interfaces

The module interfaces with the Target Interrupt module and the system servo

11.3.3 - External Data Dependencies

No external data

11.3.4 - Internal Data Dependencies

Boolean value

11.3.5 - Process/Pseudo code

```
private boolean tarFinCon(){
        if(Target_Fin)
        return true;
        else
        return false;
}
```

IRBS Design

The Intelligent rotating base station, or IRBS, will consist of two servos, pan and tilt brackets, an accelerometer, and the aluminum launch pad. The launch pad will be rotated in the proper direction by the use of the two servos. It will also have an accelerometer to report the platform back to the launch control box. All of these components are described in more detail in section 14.

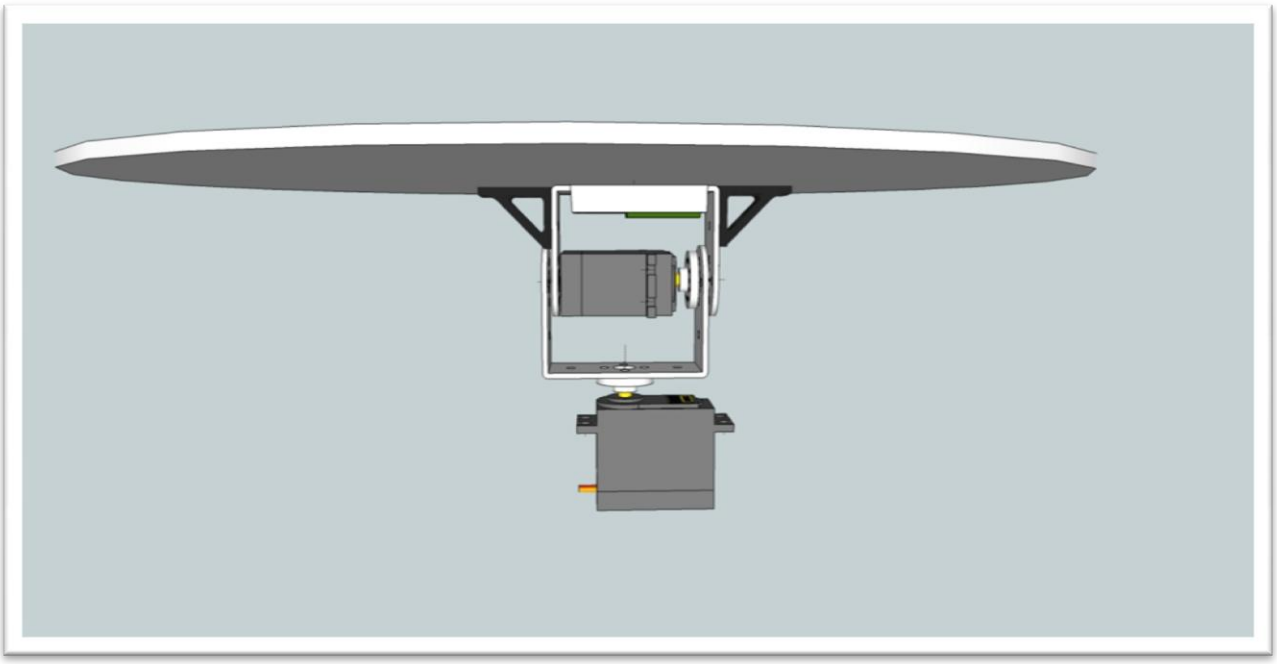

FIGURE 11-2 - IRBS DESIGN PROFILE VIEW

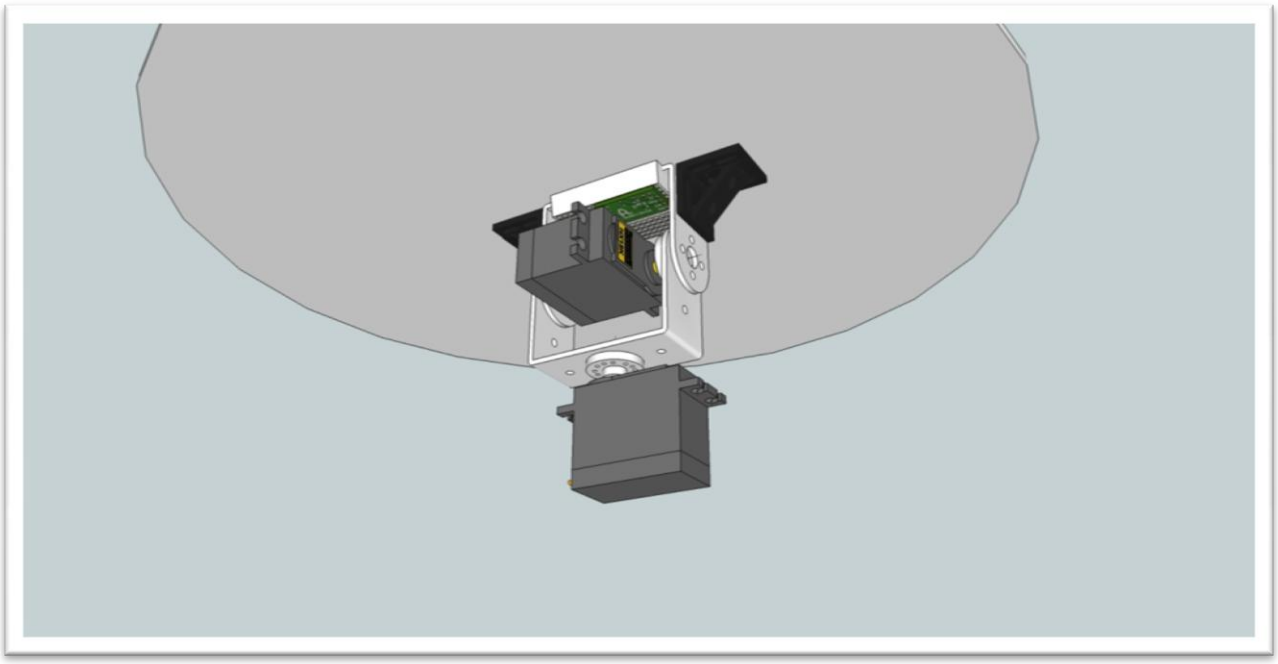

FIGURE 11-3 - IRBS DESIGN UNDER PAD VIEW #1

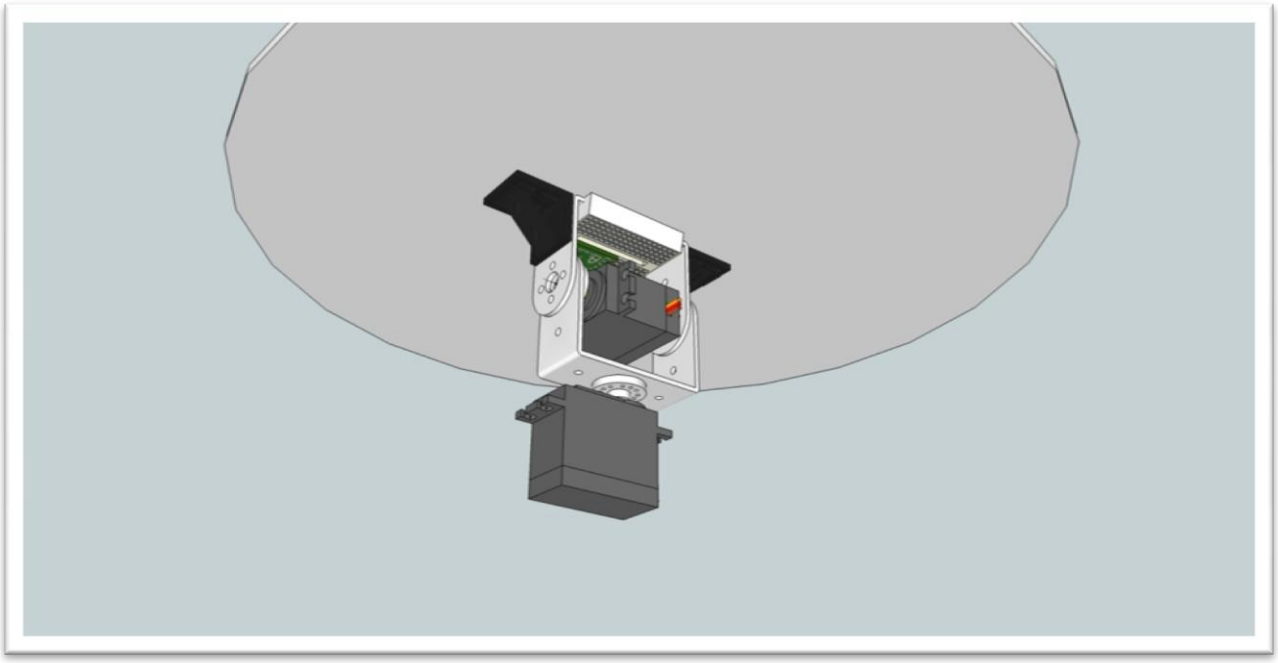

FIGURE 11-4 - IRBS DESIGN UNDER PAD VIEW #2

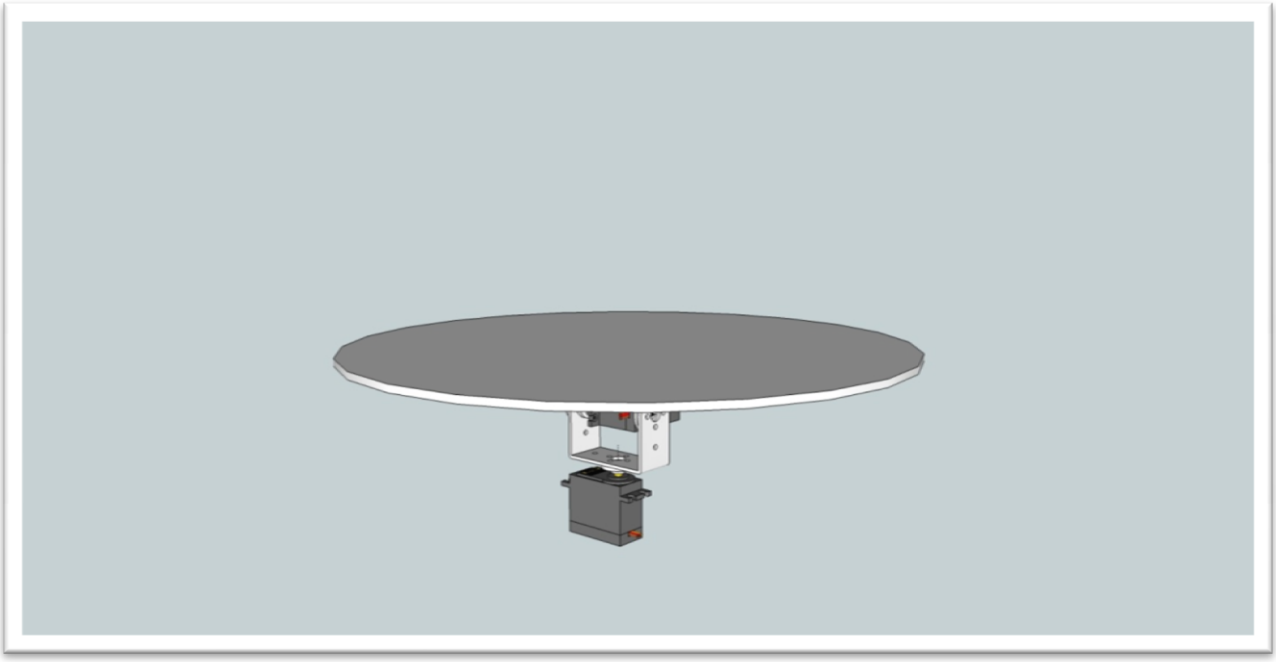

FIGURE 11-5 - IRBS DESIGN ABOVE VIEW

12. - IRBS Hardware Design

Figures 13-1 and 13-2 show the IRBS bread board layout and schematic layout. For more details, see section 14.

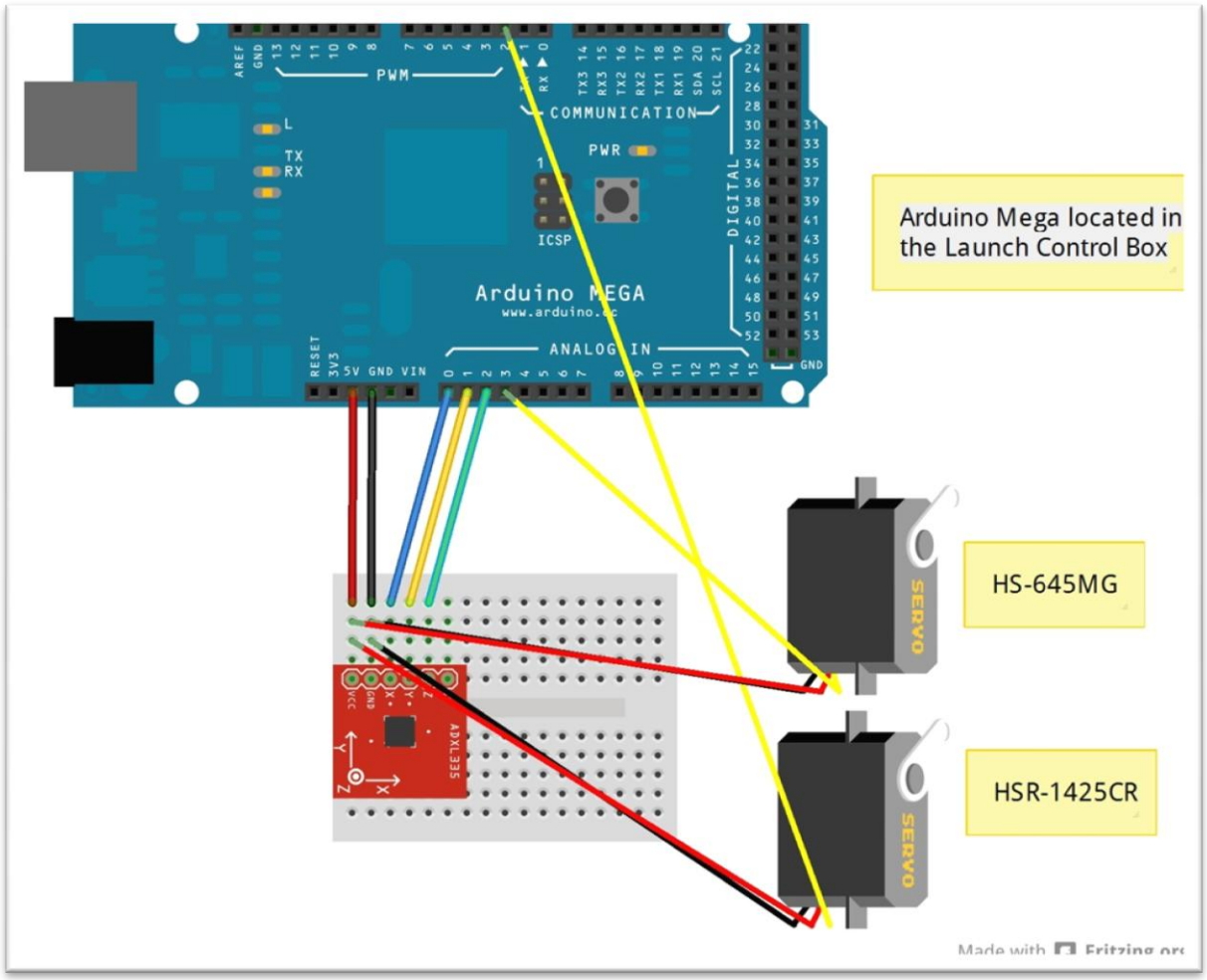

FIGURE 12-1- IRBS BREAD BOARD LAYOUT

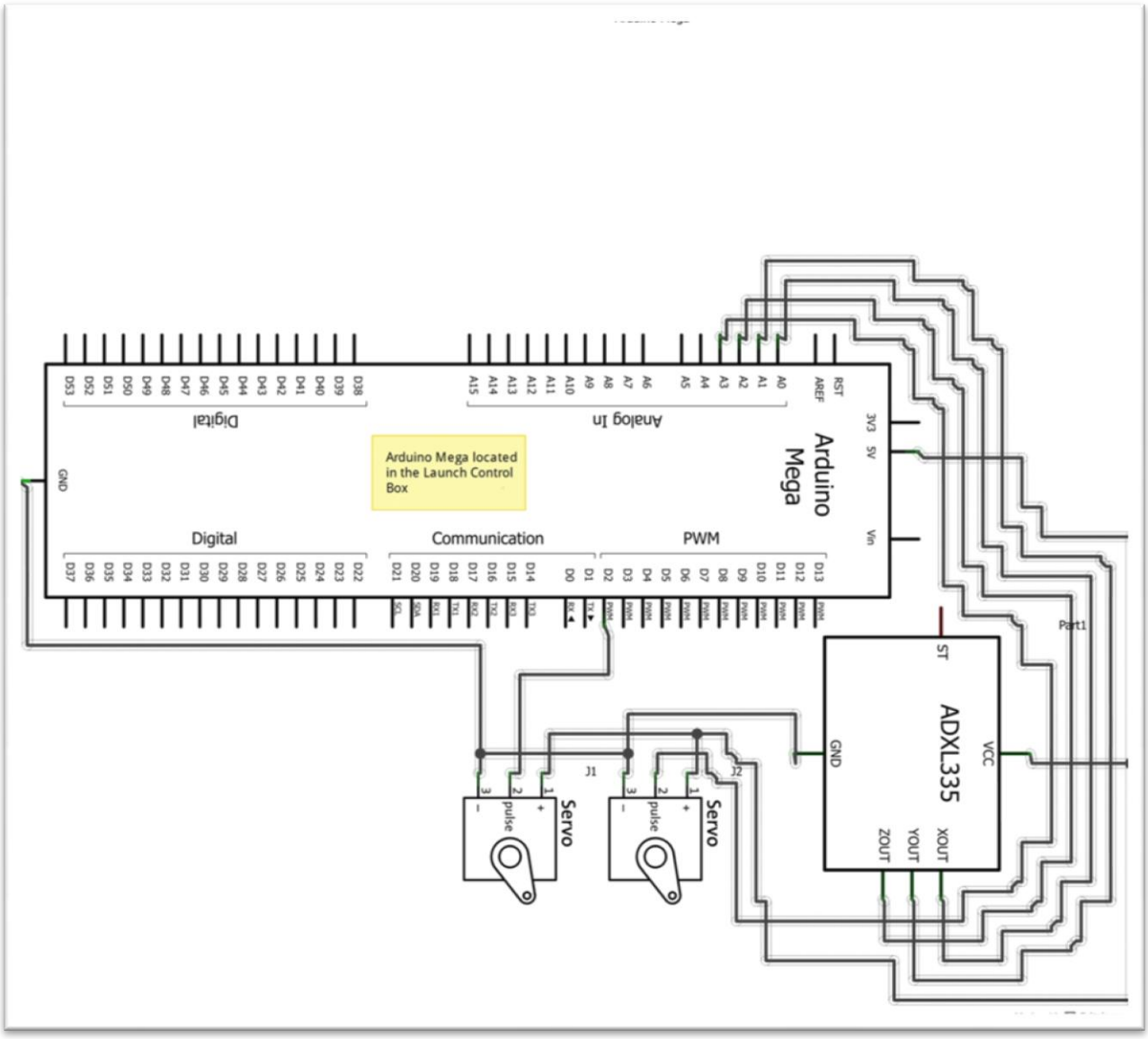

FIGURE 12-2- IRBS SCHEMATIC LAYOUT

13. - IRBS Hardware Components

13.1 - Overview

Figures in section 12 show physical design of the IRBS. The IRBS hardware components section shall describe all of the hardware components used in the Intelligent Rotating Base Station. Each component shall have a section describing its purpose, specifications and interfaces.

13.2 - HSR-1425CR Continuous Rotation Servo

FIGURE 13-1- HSR-1425CR CONTINUOUS ROTATION SERVO

13.2.1 - **Purpose**

The purpose of this servo is the pan the launch pad to the appropriate angle. This will allow the other servo to tilt in the appropriate direction into the wind.

13.2.2 - **Specifications**

- Control System: +Pulse Width Control 1500usec Neutral
- Required Pulse: 4.8-6.0 Volt Peak to Peak Square Wave
- Operating Voltage Range: 4.8-6.0 Volts
- Operating Temperature Range: -20 to +60 Degree C (-4F to +140F)
- Operating Speed (4.8V): 44 RPM at no load
- Operating Speed (6.0V): 52 RPM at no load
- Operating Torque (4.8V): 38.8 oz-in (2.8 kg-cm)
- Operating Torque (6.0V): 42 oz-in (3.1 kg-cm)
- Direction: Clockwise/Pulse Traveling 1500 to 1900usec

- Connector Wire Length: 7" (178mm)
- Dimensions: 1.59" x 0.77"x 1.44" (40.6 x 19.8 x 36.6mm)
- Weight: 1.47oz (41.7g)

13.2.3 - **Interfaces**

The HSR-1425CR Continuous Rotation Servo will interface with the Arduino Mega inside of the Launch Control Box. It will use one digital pin on the Arduino; see figures 13-1 and 13-2 of section 13.

13.3 - HS-645MG Servo Motor

FIGURE 13-2 - HS-645MG SERVO MOTOR

13.3.1 - **Purpose**

The purpose of this servo is to tilt the launch pad to an appropriate angle into the wind.

13.3.2 - **Specifications**

- Control System: +Pulse Width Control 1500usec Neutral
- Required Pulse: 3-5 Volt Peak to Peak Square Wave
- Operating Voltage: 4.8-6.0 Volts
- Operating Temperature Range: -20 to +60 Degree C
- Operating Speed (4.8V): 0.24sec/60° at no load
- Operating Speed (6.0V): 0.20sec/60° at no load
- Stall Torque (4.8V): 106.93 oz/in. (7.7kg.cm)
- Stall Torque (6.0V): 133.31 oz/in. (9.6kg.cm)
- Operating Angle: 45 Deg. one side pulse traveling 400usec
- 360 Modifiable: Yes

- Direction: Clockwise/Pulse Traveling 1500 to 1900usec
- Connector Wire Length: 11.81" (300mm)
- Dimensions: 1.59" x 0.77"x 1.48" (40.6 x 19.8 x 37.8mm)
- Weight: 1.94oz. (55.2g)

13.3.3 - **Interfaces**

The HS-645MG Servo will interface with the Arduino Mega inside of the Launch Control Box. It will use one analog pin on the Arduino; see figures 13-1 and 13-2 of section 13.

13.4 - ADXL326 - 5V ready triple-axis accelerometer (+-16g analog out)

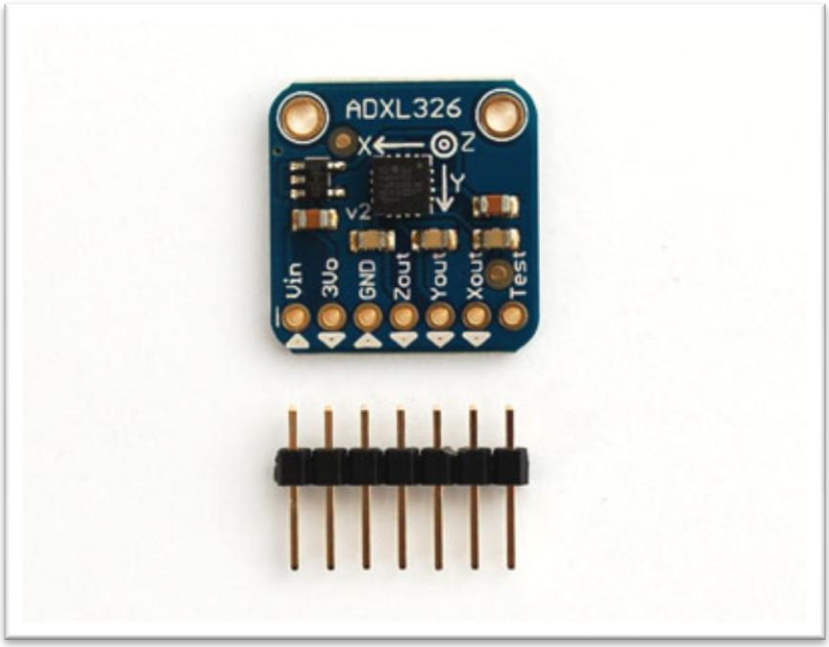

FIGURE 13-3 - ADXL326 - 5V READY TRIPLE-AXIS ACCELEROMETER

13.4.1 - **Purpose**

The purpose of the ADXL326 accelerometer is to measure the launch pad angle. The accelerometer is a safety feature to ensure that the pad does not over tilt its 30 degree maximum.

13.4.2 - **Specifications**

- Sensing Range :±19g
- Sensitivity: 57mV/g
- Voltage - Supply:1.8 V ~ 3.6 V

13.4.3 - **Interfaces**

The ADXL326 accelerometer will interface with the Arduino Mega inside of the Launch Control Box. It will use three analog pins on the Arduino; see figures 13-1 and 13-2 of section 13.

13.5 - DDT500 Direct Drive Tilt System

FIGURE 13-4 - DDT500 DIRECT DRIVE TILT SYSTEM

13.5.1 - **Purpose**

The Purpose of the DDT500 Direct Drive Tilt System is to provide two brackets that the two servos connect to. This will allow **for** flawless pan and tilt of the launch platform.

13.5.2 - **Specifications**

- 1/4” ABS plastic
- Max supported weight: 2 lbs

13.5.3 - **Interfaces**

The DDT500 Direct Drive Tilt System has no interface with any electronic device. It is attached via screws to the two servos.

13.6 - Adafruit Perma-Proto Quarter-sized Breadboard PCB

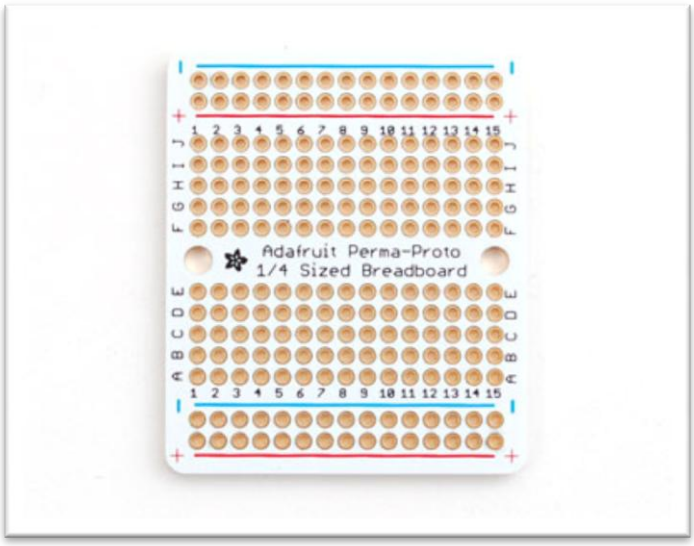

FIGURE 13-5- ADAFRUIT PERMA-PROTO QUARTER-SIZED BREADBOARD PCB

13.6.1 - **Purpose**

The Adafruit Perma-Proto Quarter-sized Breadboard PCB will allow connections to the Arduino Mega in the launch control box. This will allow for the accelerometer to have power and data flow.

13.6.2 - **Specifications**

- 15 rows of double 5-hole rows
- 4 power rails with positive/negative markings
- 1.7" x 2.0" (44mm x 55mm), 0.063" thick FR4
- 1.2mm / 0.047" drill holes
- 2 x 0.125" or 3.2mm mounting holes 1.4" apart

13.6.3 - **Interfaces**

The Adafruit perma-proto quarter-sized breadboard PCB interfaces with the Arduino Mega in the launch control box through a 5-volt pin and ground pin to power the rest of the system; see figures 13-1 and 13-2 of section 13.

14. - Launch Control Box Design

The Launch Control Box will consist of multiple switches, buttons, LED indicators, an LCD screen, a data port to control the IRBS, and connection to the rocket ignition system. The rocker switch will control the power of the unit. The three large control switches will allow the user to change the modes. The large red button will launch the rocket. The LED lights are used for debugging the system and the LCD screen allows the system to display data to the user. All of these components are described in more detail in section 17.

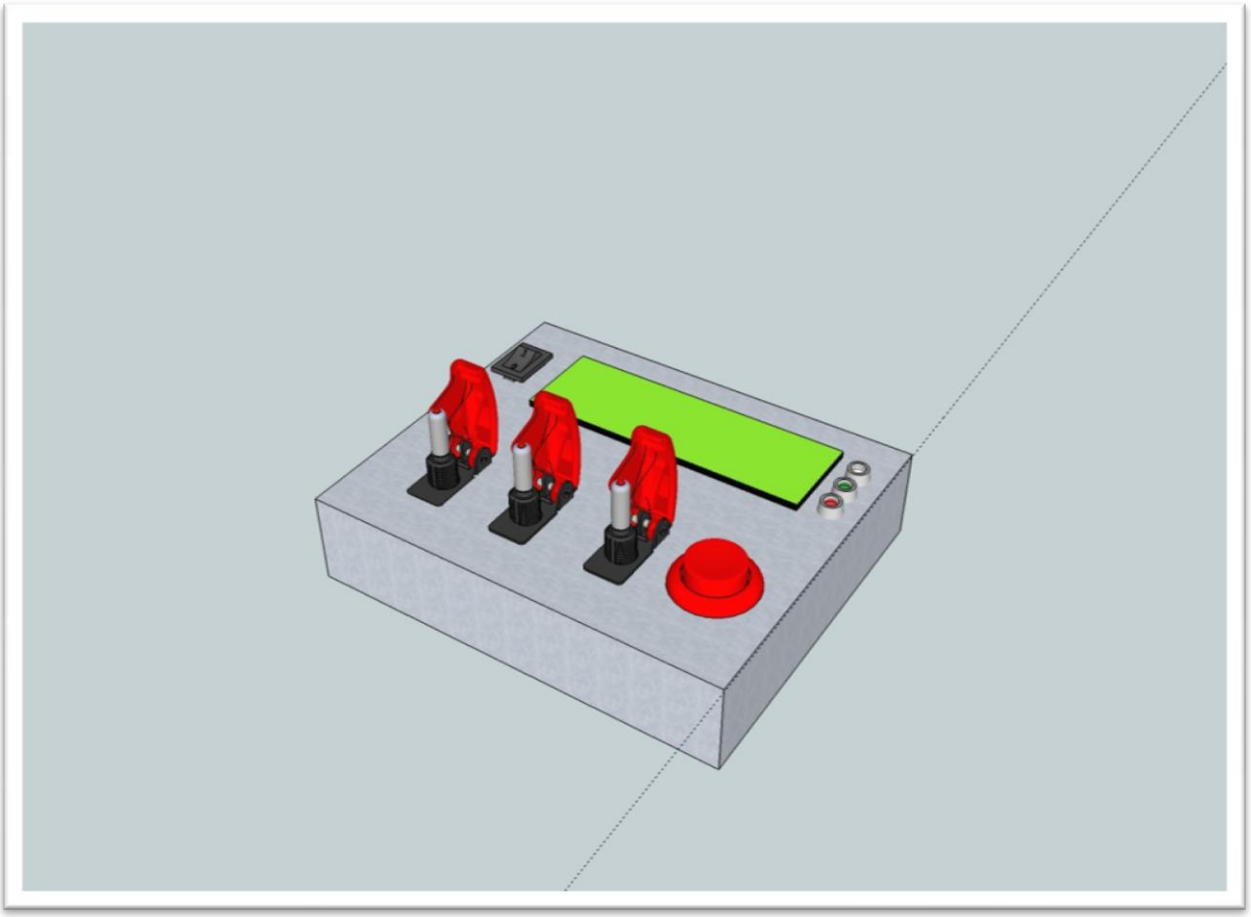

FIGURE 14-1-LAUNCH CONTROL BOX VIEW #1

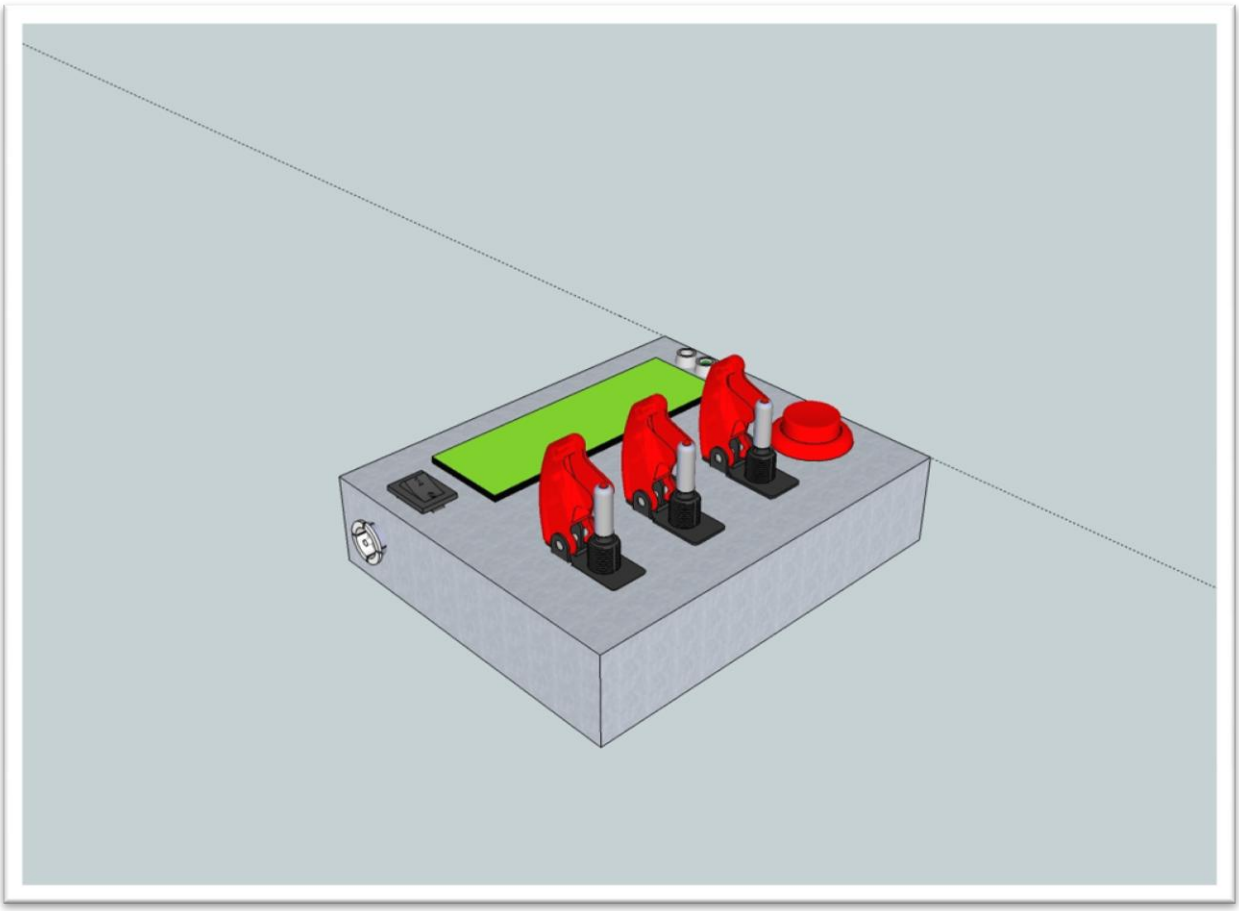

FIGURE 14-2-LAUNCH CONTROL BOX VIEW #2

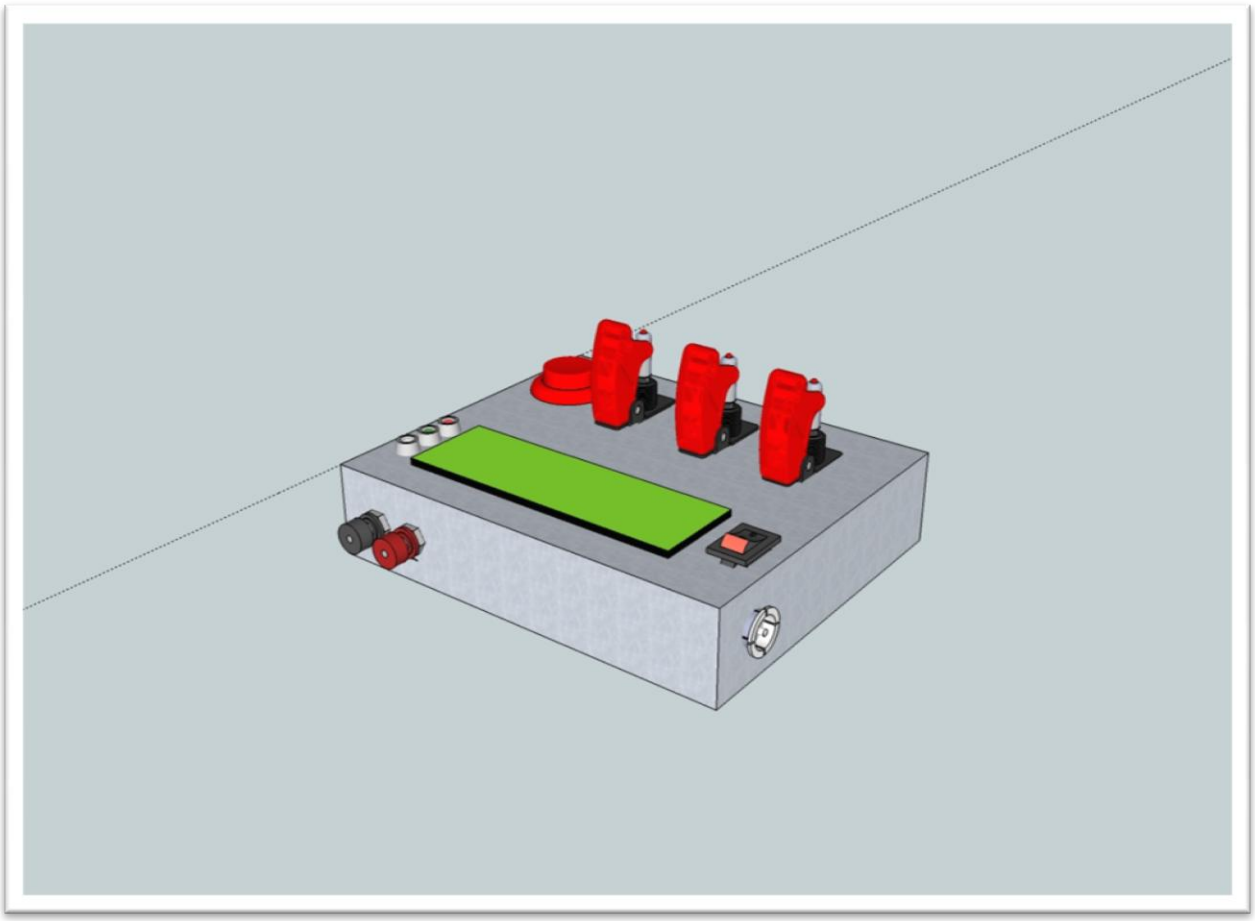

FIGURE 14-3-LAUNCH CONTROL BOX VIEW #3

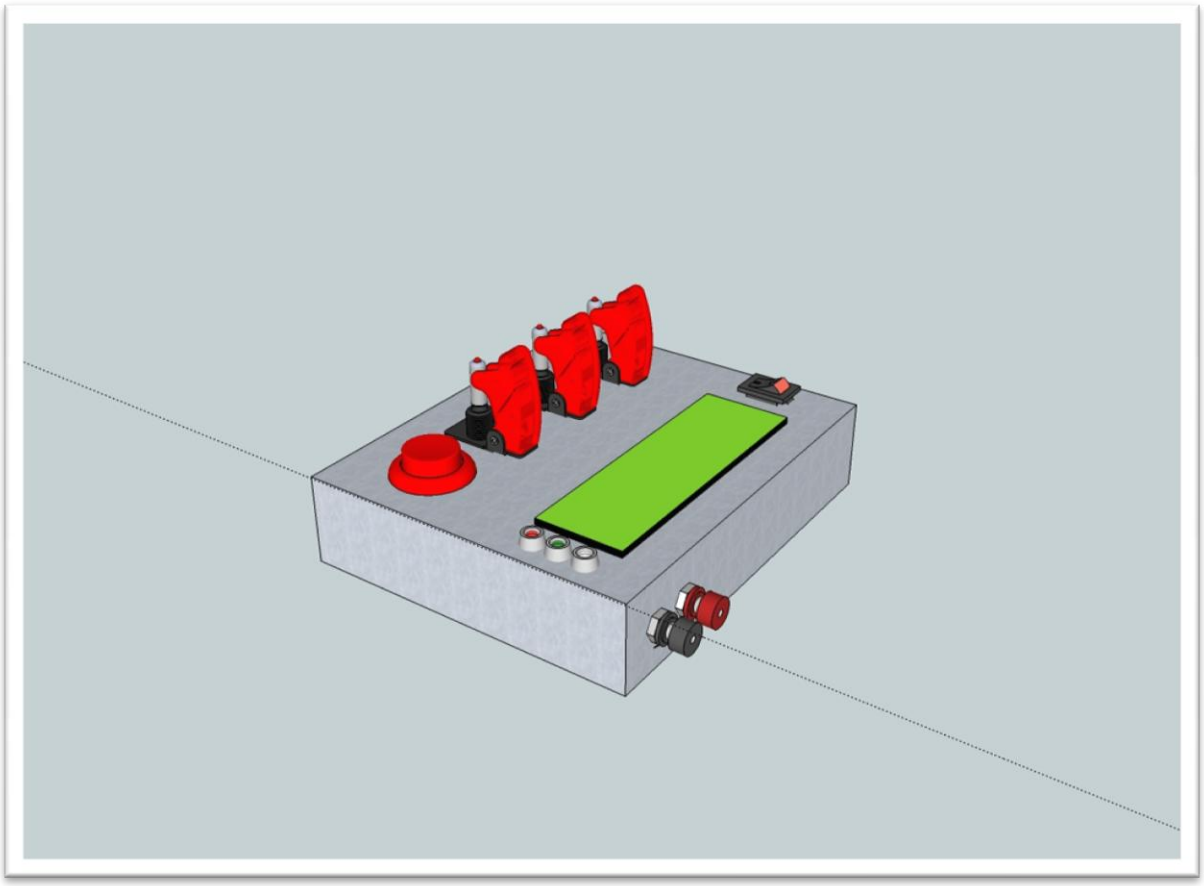

FIGURE 14-4-LAUNCH CONTROL BOX VIEW #4

15. - Launch Control Box Hardware Design

Figures 16-1 and 16-2 show launch control box bread board layout and schematic layout. For more details, see section 17.

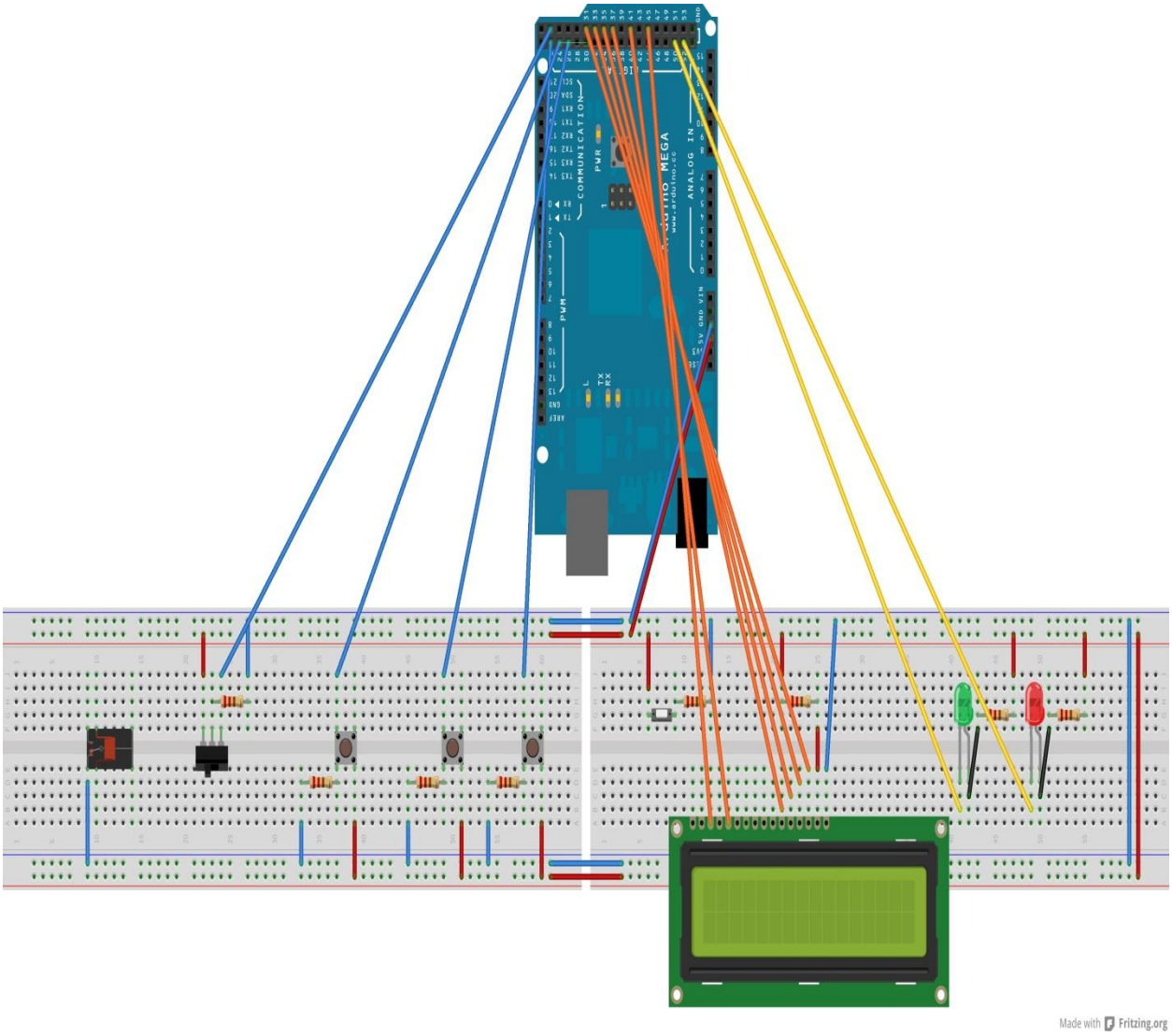

FIGURE 16-1-LAUNCH CONTROL BOX BREAD BOARD LAYOUT

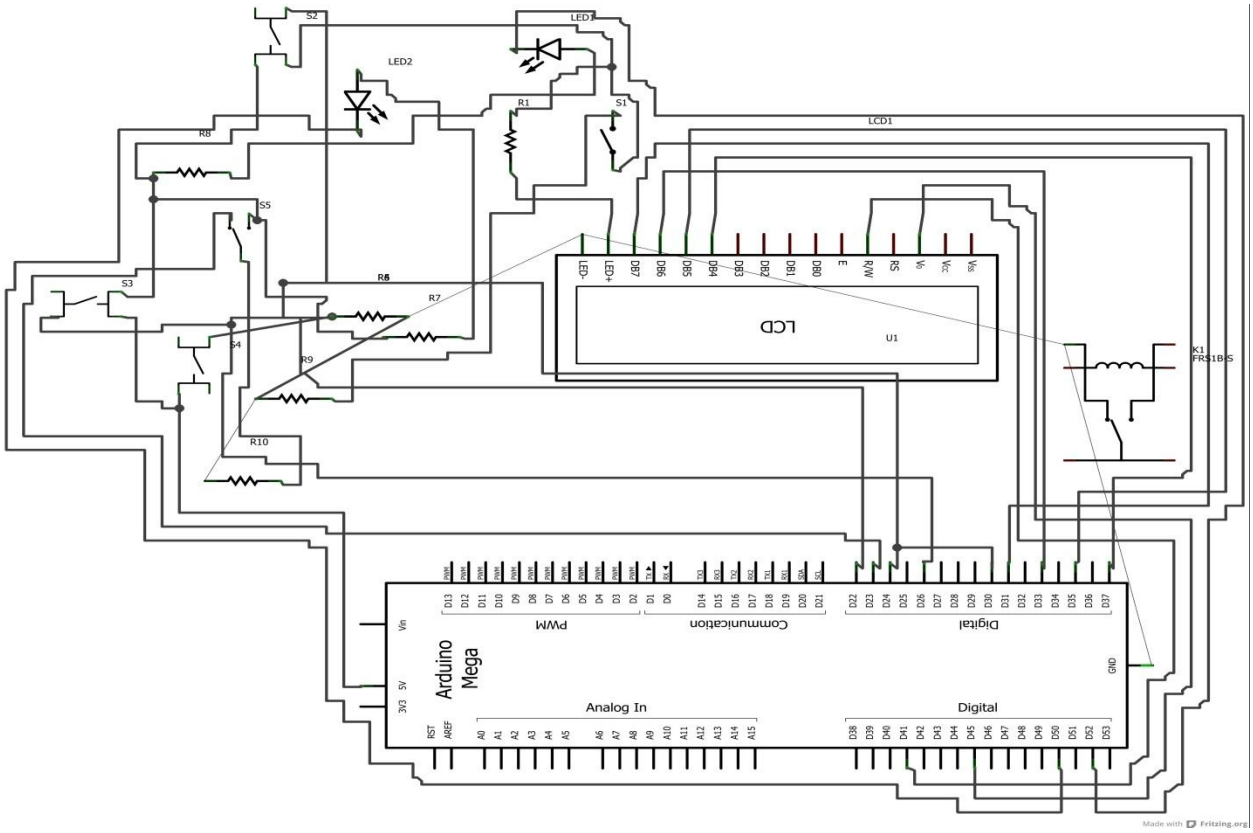

FIGURE 16-2-LAUNCH CONTROL BOX SCHEMATIC LAYOUT

16. - Launch Control Box Hardware Components

16.1 - Overview

Figures in section 15 show physical design of the launch control box. The launch control box hardware components section shall describe all of the hardware components used in the Launch Control Box. Each component shall have a section describing its purpose, specifications and interfaces.

16.2 - Arduino Mega

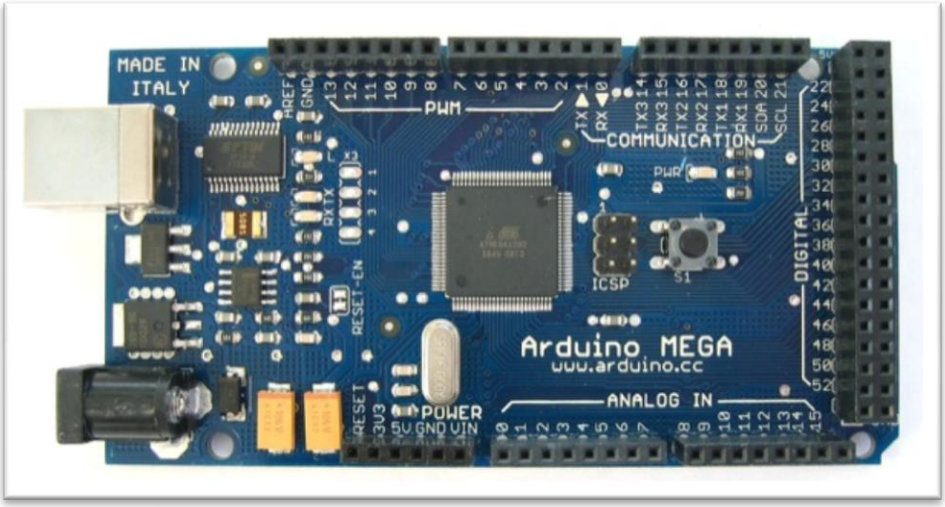

FIGURE 16-2 - ARDUINO MEGA

16.2.1 - **Purpose**

The Arduino Mega 2560 R3 DEV-11061 is to act as the mother board of the Rocket Recovery System. It will handle all the computations necessary for the system to function correctly and distribute power to the other hardware components.

16.2.2 - **Specifications**

- Microcontroller: ATmega1280
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limits): 6-20V
- Digital I/O Pins: 54 (of which 15 provide PWM output)
- Analog Input Pins: 16
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA

- Flash Memory: 128 KB of which 4 KB used by bootloader
- SRAM: 8 KB
- EEPROM: 4 KB
- Clock Speed: 16 MHz

16.2.3 - **Interfaces**

The Arduino Mega 2560 will interfaces with the Rocket Recovery System through digital, analog, TX/RX, 5 volt, **and** ground **pins** and to the other components through wires. It also interfaces through the battery holder port.

16.3 - Davis Anemometer, Standard (#7911)

FIGURE 16-3 - ANEMOMETER, STANDARD (#7911)

16.3.1 - **Purpose**

The purpose of the anemometer is to gather the wind speed and direction data.

16.3.2 - **Specifications**

- Cable Type : 4-conductor, 26 AWG
- Connector: . Modular connector (RJ-11)

16.3.3 - **Interfaces**

The anemometer will connect to a digital pin, and use a 4k7 resistor as pull up to + 5v and use a 10 to 22nF capacitor from the pin to ground to debounce the reed switch of anemometer. It will also connect to an analog pin and use a 1 to 10 µF / 16v capacitor between the pin and ground (observe C polarity) to avoid jitter.

16.4 - Rocker Switch – SPST

FIGURE 16-4-ROCKER SWITCH – SPST

16.4.1 - **Purpose**

The purpose of the rocker switch is to allow the user to turn on and off the power of the rocket recovery system.

16.4.2 - **Specifications**

- Right angle solid through hole mounting
- Rated up to 16A @ 125V

16.4.3 - **Interfaces**

The Rocker Switch will interface with the Arduino Mega 5 volt power and ground.

16.5 - Toggle Switch and Cover - Illuminated (Red)

FIGURE 16-5 - TOGGLE SWITCH AND COVER - ILLUMINATED

16.5.1 - **Purpose**

The purpose of the toggle switch and cover is to allow the users to switch between all the modes the Rocket Recovery Systems uses. The cover is an extra safety feature to prevent the user from accidently flipping a switch. The switches will also illuminate when active so the user knows when a modes are active.

16.5.2 - **Specifications**

- Rated for 12V 20A
- Includes Missile Switch Cover
- Illuminated

16.5.3 - **Interfaces**

The Switch will interface with 1 Arduino Mega digital pin. It will also need to be connected to 5v power supply and ground to provide the Illumination. Also we will need a 10K ohm pull-down resistor between the input pin and ground on the Arduino. The Arduino's internal resistors are pull-up and won't work here so we need to do this manually.

16.6 - Concave Button – Red

FIGURE 16-6 - CONCAVE BUTTON – RED

16.6.1 - **Purpose**

The purpose the Concave Button is to allow the user to launch the rocket after the countdown has finished.

16.6.2 - **Specifications**

- Microswitch: max 3A @ 120 VAC
- Microswitch reliability tested to 10,000,000 cycles
- Includes 3 terminal microswitch
- Net weight: 25g

16.6.3 - **Interfaces**

The Switch will interface with 1 Arduino Mega digital pin.

16.7 - RGB backlight positive LCD 16x2

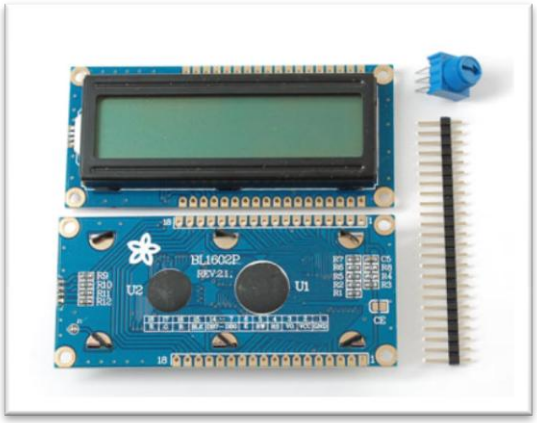

FIGURE 16-7 - RGB BACKLIGHT POSITIVE LCD 16X2

16.7.1 - **Purpose**

The purpose of the RGB backlight positive LCD 16x2 is to allow the system to send output to the user in some readable format.

16.7.2 - **Specifications**

- 16 characters wide, 2 rows
- Black text on multi-color background
- Connection port is 0.1" pitch, single row for easy breadboarding and wiring
- Single RGB LED backlight included can be dimmed easily with a resistor or PWM and uses much less power than LCD with EL (electroluminescent) backlights
- Built in character set supports English/Japanese text, see the HD44780 datasheet for the full character set
- Up to 8 extra characters can be created for custom glyphs or 'foreign' language support

16.7.3 - **Interfaces**

The RGB backlight positive LCD 16x2 interfaces with the Arduino Mega though 6 digital pins. (Any analog/digital pins can be used) and 3 PWM pins for the backlight; see figures 16-1 and 16-2 of section 16.

16.8 - LED Indicators

FIGURE 16-8 - LED INDICATORS

16.8.1 - **Purpose**
The purpose of the LED indicators is to allow the system to notify the user modes and problems.

16.8.2 - **Specifications**

- 5mm diameter
- 660 nm wavelength
- 1.85-2.5V Forward Voltage, at 20mA current
- 250 mcd typical brightness

16.8.3 - **Interfaces**
The LED Indicators interface with one digital pin on the Arduino Mega; see figures 16-1 and 16-2 of section 16.

16.9 - Relay SPDT Sealed

FIGURE 16-9 - RELAY SPDT SEALED

16.9.1 - **Purpose**

The purpose of the relay is to close the circuit on the attached 9v battery launcher circuit. The purpose of this circuit is to send the charge to the rocket engine fuse.

16.9.2 - **Specifications**

- 5V DC SPDT Relay
- Rated up to 5A
- Fully Sealed

16.9.3 - **Interfaces**

Interfaces with the 9 volt battery circuit.

16.10 - Battery Holder

FIGURE 16-10 - BATTERY HOLDER

16.10.1 - **Purpose**

The purpose of the battery holder is to distribute power to the Launch Control Box provided by the rechargeable 9V battery.

16.10.2 - **Specifications**

This is a 9V battery pack with on/off switch and a pre-attached 5.5mm/2.1mm barrel plug.

16.10.3 - **Interfaces**

The battery holder provides power to the Launch Control Box by interfacing with the Arduino.

16.11 - 9 Volt Battery

FIGURE 16-2 - 9 VOLT BATTERY

16.11.1 - **Purpose**

The purpose of the 9V battery is to provide power to the Launch Control Box.

16.11.2 - **Specifications**

Provide 9 volts.

16.11.3 - **Interfaces**

The 9 volt battery provides power to the Launch Control Box by interfacing with the battery holder.

17. - RRM Hardware Design

Figures 18-1 and 18-2 show RRM bread board layout and schematic layout. For more details, see section 19.

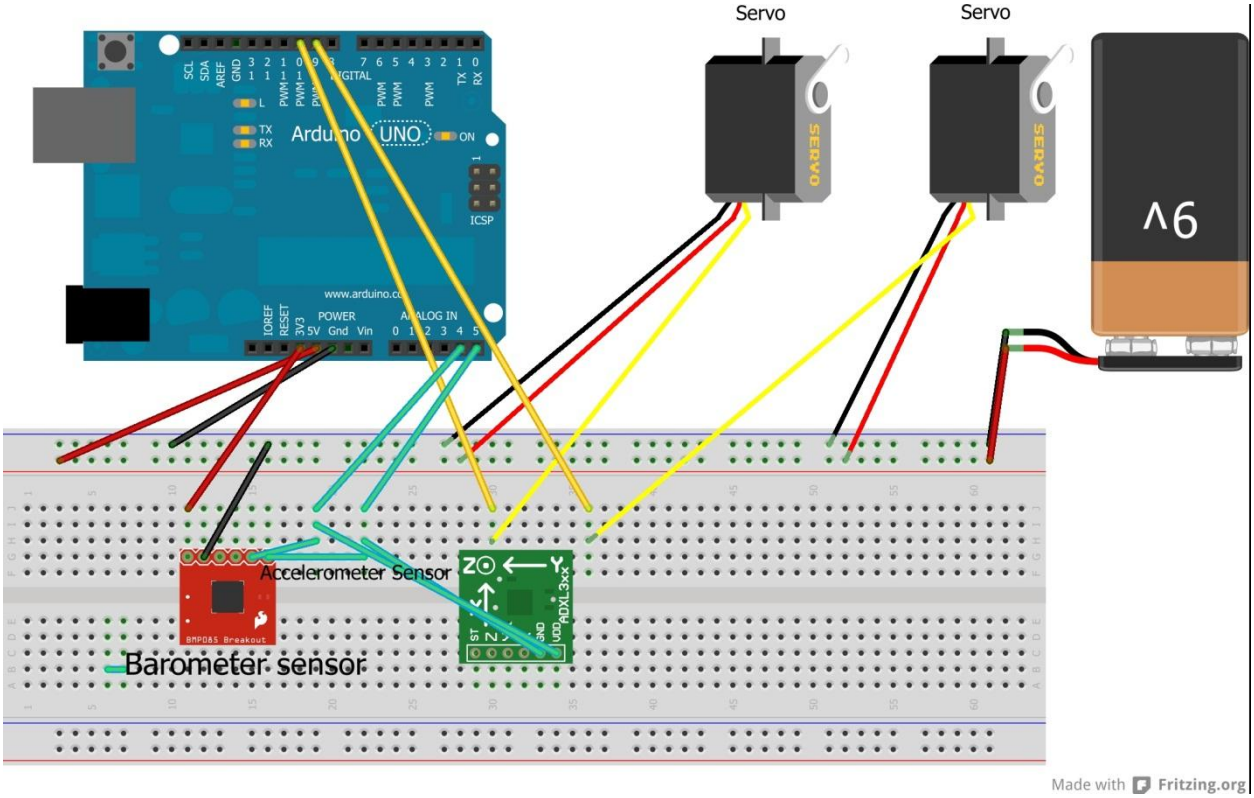

FIGURE 18-1-RRM BREAD BOARD LAYOUT

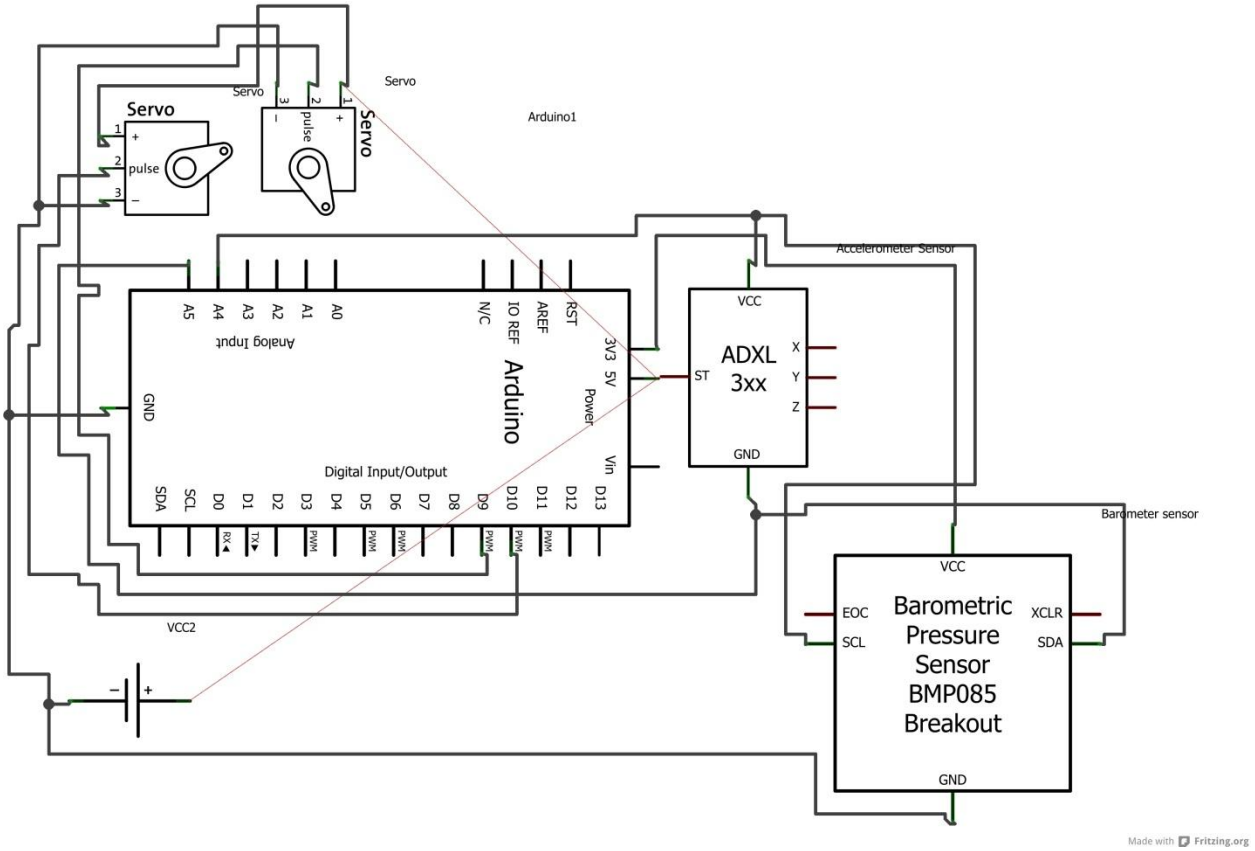

FIGURE 18-2-RRM SCHEMATIC LAYOUT

18. - RRM Hardware Components

18.1 - Overview

The hardware section shall describe all of the hardware components used in the Rocket Recovery Module. Each component shall have a section describing its purpose, specifications and interfaces.

18.2 - Arduino Uno

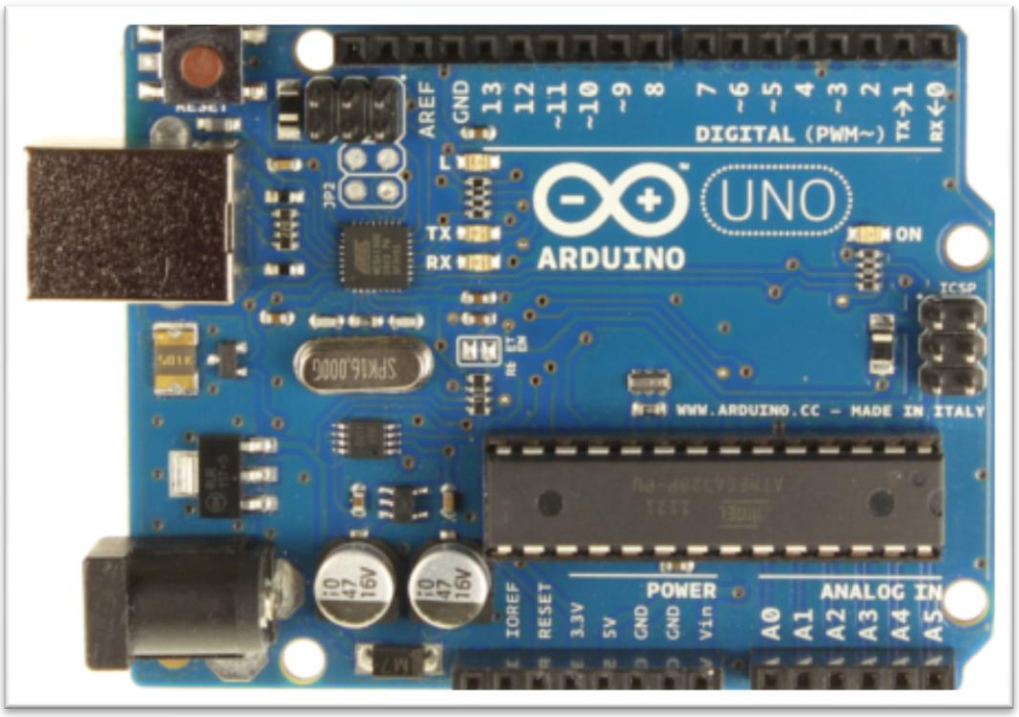

FIGURE 18-1 - ARDUINO UNO

18.2.1 - **Purpose**

The Arduino Uno is to act as the mother board of the Rocket Recovery System. It will handle all the computations necessary for the system to function correctly and distribute power to the other hardware components.

18.2.2 - **Specifications**

- Microcontroller: ATmega328
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limits): 6-20V

- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB of which .5 KB used by bootloader
- SRAM: 2 KB
- EEPROM: 1 KB
- Clock Speed: 16 MHz

18.2.3 - **Interfaces**

The Arduino Uno will interfaces with the Rocket Recovery System through digital, analog, TX/RX, 5 volt, and ground **pins** and to the other components through wires. It also interfaces through the battery holder port; see figures 18-1 and 18-2 of section 18.

18.3 - ADXL326 - 5V ready triple-axis accelerometer (+-16g analog out)

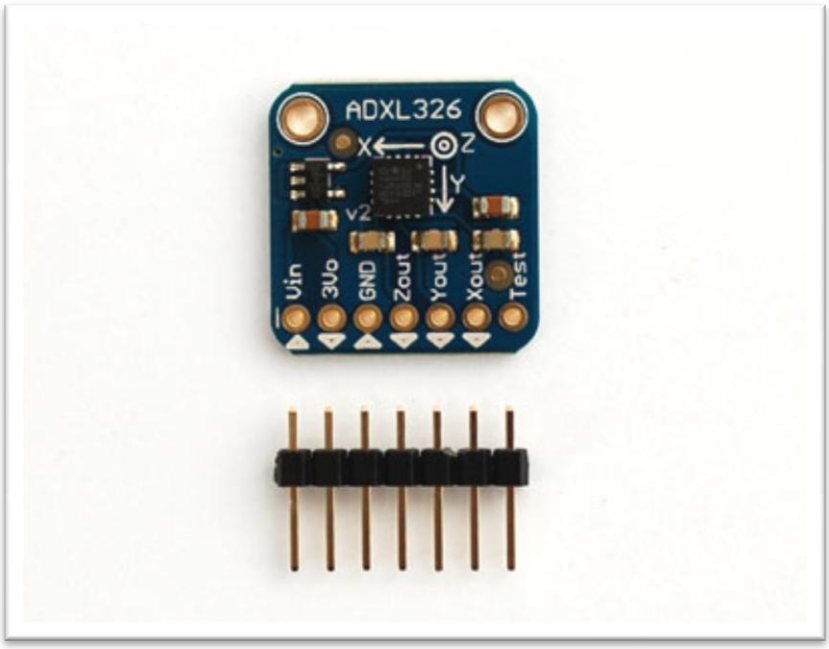

FIGURE 18-2- ADXL326 - 5V READY TRIPLE-AXIS ACCELEROMETER

18.3.1 - **Purpose**

The purpose of the ADXL326 accelerometer is to measure the change in position of the rocket during flight so that calculations can be made to stabilize the rocket.

18.3.2 - **Specifications**

- Sensing Range :±19g
- Sensitivity: 57mV/g
- Voltage - Supply:1.8 V ~ 3.6 V

18.3.3 - **Interfaces**

The ADXL326 accelerometer will interface with the Arduino Uno inside of the Rocket (RRM). It will use three analog pins on the Arduino; see figures 18-1 and 18-2 of section 18.

18.4 - BMP085 Barometric Pressure/Temperature/Altitude Sensor- 5V ready

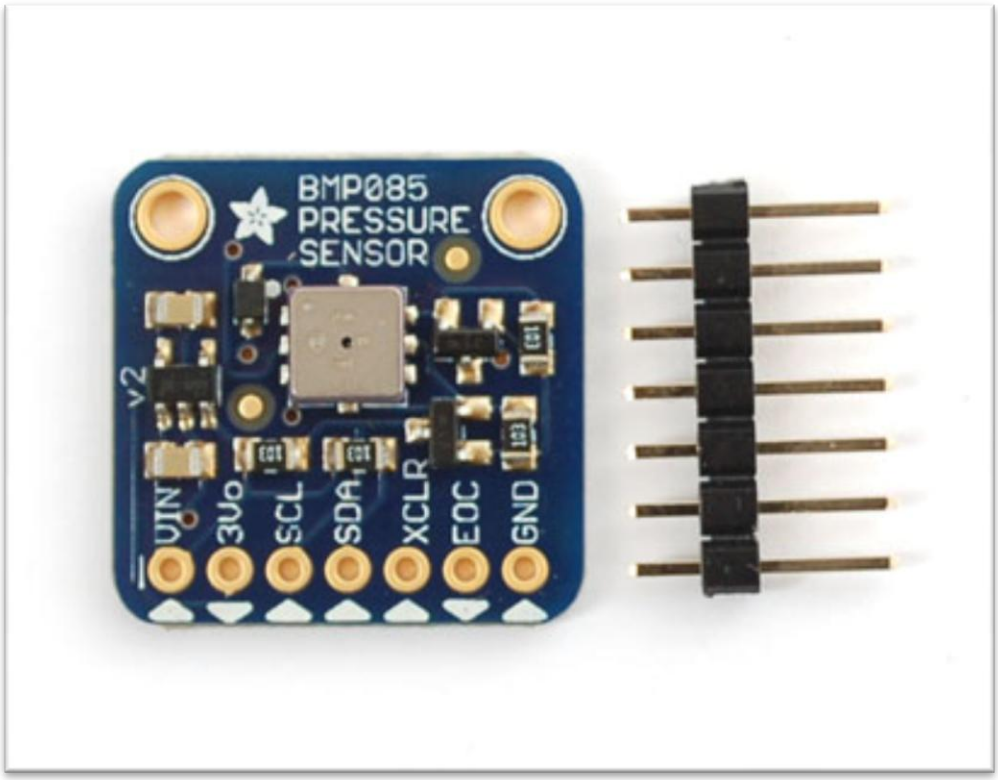

FIGURE 18-3- BMP085 BAROMETRIC PRESSURE/TEMPERATURE/ALTITUDE SENSOR

18.4.1 - **Purpose**

The purpose of the BMP085 Barometric Pressure Sensor is to measure the current air pressure the rocket is at. The air pressure can be used to calculate the current altitude of the rocket.

18.4.2 - **Specifications**

- Logic: 3 to 5V compliant
- Pressure sensing range: 300-1100 hPa (9000m to -500m above sea level)
- Up to 0.03hPa / 0.25m resolution
- -40 to +85°C operational range, +-2°C temperature accuracy

18.4.3 - **Interfaces**

The BMP085 Barometric Pressure Sensor will interface with the Arduino Uno inside of the Rocket (RRM). It will use two analog pins on the Arduino; see figures 18-1 and 18-2 of section 18.

18.5 - HS-645MG Servo Motor

FIGURE 18-4 - HS-645MG SERVO MOTOR

18.5.1 - **Purpose**

The purpose of this servo is to move the attached control surface to stabilize and turn the rocket.

18.5.2 - **Specifications**

- Control System: +Pulse Width Control 1500usec Neutral
- Required Pulse: 3-5 Volt Peak to Peak Square Wave
- Operating Voltage: 4.8-6.0 Volts
- Operating Temperature Range: -20 to +60 Degree C
- Operating Speed (4.8V): 0.24sec/60° at no load
- Operating Speed (6.0V): 0.20sec/60° at no load

- Stall Torque (4.8V): 106.93 oz/in. (7.7kg.cm)
- Stall Torque (6.0V): 133.31 oz/in. (9.6kg.cm)
- Operating Angle: 45 Deg. one side pulse traveling 400usec
- 360 Modifiable: Yes
- Direction: Clockwise/Pulse Traveling 1500 to 1900usec
- Connector Wire Length: 11.81" (300mm)
- Dimensions: 1.59" x 0.77"x 1.48" (40.6 x 19.8 x 37.8mm)
- Weight: 1.94oz. (55.2g)

18.5.3 - **Interfaces**

The HS-645MG Servo will interface with the Arduino Uno inside of the rocket (RRM). It will use one analog pin on the Arduino; see figures 18-1 and 18-2 of section 18.

18.6 - Battery Holder

FIGURE 18-50 - BATTERY HOLDER

18.6.1 - **Purpose**

The purpose of the battery holder is to distribute power to the Launch Control Box provided by the rechargeable 9V battery.

18.6.2 - **Specifications**

This is a 9V battery pack with on/off switch and a pre-attached 5.5mm/2.1mm barrel plug.

18.6.3 - **Interfaces**

The battery holder provides power to the Launch Control Box by

interfacing with the Arduino; see figures 18-1 and 18-2 of section 18.

18.7 - 9 Volt Battery

FIGURE 18-6 - 9 VOLT BATTERY

18.7.1 - **Purpose**

The purpose of the 9V battery is to provide power to the Launch Control Box.

18.7.2 - **Specifications**

Provide 9 volts.

18.7.3 - **Interfaces**
The 9 volt battery provides power to the Launch Control Box by interfacing with the battery holder.

19. - SD-12 Rocket Design

19.1 - Rocket Design

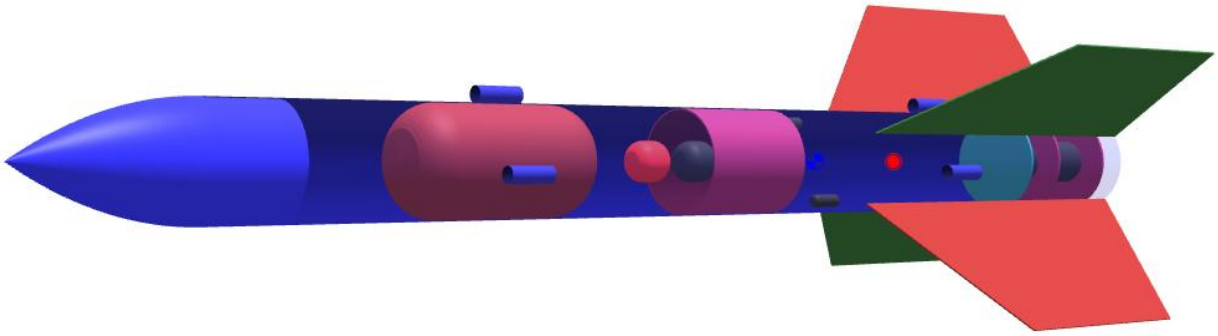

FIGURE 7 - ROCKET DESIGN 3D

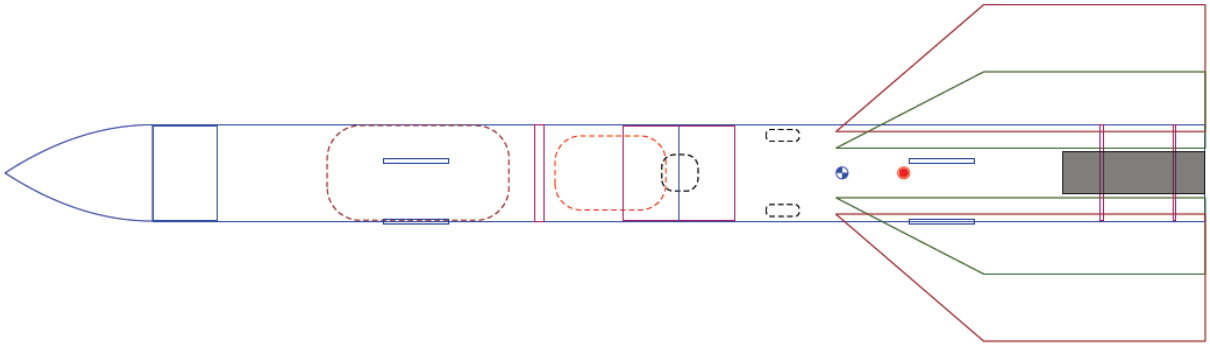

FIGURE 8 - ROCKET DESIGN 2D

19.2 - Rocket Motor Specifications

Rocket

Stages: 1

Mass (with motor): 535 g

Stability: 1.67 in

CG: 57.6 cm

CP: 61.8 cm

F50-6

Altitude	374 m
Flight Time	70.0 s
Time to Apogee	7.9 s
Velocity off Pad	16.4 m/s
Max Velocity	113 m/s
Velocity at Deployment	4.95 m/s
Landing Velocity	6.03 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
F50	55.8 N	1.37 s	79.6 N	76.8 Ns	10.65:1	37.9 g	0.029/0.098 m

20. - SD-12 Components

	Nose cone Estes PNC-80BB	Polystyrene PS (0.86 g/cm³)	Parabolic series	Len: 10.2 cm	Mass: 36.9 g
	Body tube Estes EST 3090	Paper (0.609 g/cm³)	Dia$_{in}$ 6.57 cm Dia$_{out}$ 6.6 cm	Len: 36.2 cm	Mass: 6.95 g
	RRM Section		Dia$_{out}$ 6.5 cm		Mass: 100 g
	Parachute	Polyethylene (thin) (15.0 g/m²)	Dia$_{out}$ 61.0 cm	Len: 7.62 cm	Mass: 11.0 g
	Shroud Lines	Elastic cord (round 2 mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 61.0 cm	
	Tube coupler Estes JT-80C	Paper (0.609 g/cm³)	Dia$_{in}$ 6.27 cm Dia$_{out}$ 6.48 cm	Len: 7.62 cm	Mass: 9.44 g
	Shock cord	Elastic cord (flat 6 mm, 1/4 in) (4.3 g/m)		Len: 122 cm	Mass: 5.24 g
	Launch lug Estes EST 3090	Cardboard (0.68 g/cm³)	Dia$_{in}$ 0.105 cm Dia$_{out}$ 0.305 cm	Len: 4.44 cm	Mass: 0.194 g
	Launch lug Estes EST 3090	Cardboard (0.68 g/cm³)	Dia$_{in}$ 0.105 cm Dia$_{out}$ 0.305 cm	Len: 4.44 cm	Mass: 0.194 g
	Bulkhead	Balsa (0.17 g/cm³)	Dia$_{out}$ 6.6 cm	Len: 0.635 cm	Mass: 3.7 g
	Body tube Estes EST 3090	Paper (0.609 g/cm³)	Dia$_{in}$ 6.57 cm Dia$_{out}$ 6.6 cm	Len: 36.2 cm	Mass: 6.95 g
	Clipped Delta fin set #1 (1)	Plywood (birch) (0.63 g/cm³)	Thick: 0.476 cm		Mass: 61.3 g
	Clipped Delta fin set #2 (1)	Plywood (birch) (0.63 g/cm³)	Thick: 0.476 cm		Mass: 61.3 g
	Clipped Delta fin set #3 (1)	Plywood (birch) (0.63 g/cm³)	Thick: 0.476 cm		Mass: 61.3 g
	Clipped Delta fin set #4 (1)	Plywood (birch) (0.63 g/cm³)	Thick: 0.476 cm		Mass: 61.3 g
	Centering ring	Cardboard (0.68 g/cm³)	Dia$_{in}$ 0 cm Dia$_{out}$ 6.57 cm	Len: 0.2 cm	Mass: 4.62 g
	Centering ring	Cardboard (0.68 g/cm³)	Dia$_{in}$ 0 cm Dia$_{out}$ 6.57 cm	Len: 0.2 cm	Mass: 4.62 g
	Servo		Dia$_{out}$ 0.8 cm		Mass: 7.8 g
	Servo		Dia$_{out}$ 0.8 cm		Mass: 7.8 g
	Launch lug Estes EST 3090	Cardboard (0.68 g/cm³)	Dia$_{in}$ 0.105 cm Dia$_{out}$ 0.305 cm	Len: 4.44 cm	Mass: 0.194 g

21. - Traceability Matrices

In order to verify that certain customer and performance requirements are satisfied, Team MASS used requirements traceability matrix. Requirements traceability matrix is produced by generating a table, which specifies the modules that fulfill certain requirements.

		Requirements								
		3.1 Rocket lands where it was launched from	**3.5** IRBS – Preparation Mode	**3.6** IRBS – Launch Mode	**3.9** IRBS Rotation	**3.10** IRBS Pad Pitch	**3.11** RRS Abort Countdown	**3.12** IRBS Wind Speed Detection	**5.5** IRBS Modes - Time	**5.6** RRM – Microcontroller instructions per second
Modules	Button State	✓	✓	✓			✓		✓	
	RPM	✓	✓					✓		
	Direction	✓	✓							
	Calibrate	✓	✓					✓		
	Accelerometer Reading	✓	✓							
	Get Processed State	✓	✓							
	Format Data	✓	✓	✓			✓		✓	
	Print	✓	✓	✓			✓		✓	
	Verify Accelerometer	✓	✓							
	Verify Anemometer	✓	✓							
	Encapsulate Wind Data	✓	✓							
	Calculate Wind Speed	✓	✓							
	Calculate Wind Direction	✓	✓							
	Table Lookup	✓	✓							
	Set Wind Speed	✓	✓	✓						
	Set Wind Direction	✓	✓	✓						
	Set Flight Data	✓	✓	✓						
	Get Wind Data	✓	✓		✓	✓				
	Rotate Pan Servo	✓	✓		✓	✓				
	Rotate Tilt Servo	✓	✓		✓	✓				
	Get Flight Data	✓		✓	✓					
	Pack Data	✓		✓	✓					
	Send Flight Data	✓		✓	✓					
	Unpack Data	✓		✓	✓					
	Set ACK	✓		✓	✓					
	Unpack	✓		✓	✓					
	Pack	✓		✓	✓					

	Send ACK	✓		✓	✓					
	Accelerometer Reading	✓								
	Barometer Reading	✓								
	Verify Accelerometer	✓								✓
	Verify Barometer	✓								✓
	Calculate Altitude	✓								✓
	Target Interrupt	✓								✓
	Offset Calculation	✓								✓
	Offset Fin Controller	✓								
	Target Fin Controller	✓								

22. - Quality Assurance

22.1 - Test Plans and Procedures

Team Mass will take advantage of the modularity of the project design in carrying out the testing to achieve maximum productivity and efficiency. For a start each component will be tested using unit testing to be sure that no component is faulty or damaged before soldering. Then the group of components that made up a particular module will be tested together for functionality. On passing the test, the module will be tested with other modules in the same subsystem after which the subsystem will be tested with other subsystems in the same layer using the integration testing. Finally, the system verification testing will be conducted to ensure all the customer requirements are met and the system is robust by testing all the layers together as one.

The team other ways of testing the quality and completeness of the design are requirement mapping and test cases. The Detailed Designed Specification (DDS) was tested for design completeness by static testing against the requirements. As shown in requirement mapping, each requirement is matched against a set of design components. Rows that have no corresponding design components were requirements that do not have any consideration in the design. Some of the test cases will be provided in this chapter. However, complete and thorough test cases will only be provided only in System Test Plan.

22.2 - Module/Unit Test

23.2.1 Data Input Layer

23.2.1.1 User Input

The User Input shall be able to detect and respond to physical button presses from the user as well as convert the digital signal into a usable software object.

23.2.1.2 Anemometer Input

The Anemometer Input shall be able to calibrate the analog digital input from the anemometer and convert it to digital signal for verification.

23.2.1.3 Accelerometer Input

The Accelerometer Input shall be able to detect and read the analog digital input from the accelerometer for verification.

23.2.2 User Interface Layer

23.2.2.1 Get Data

The Get Data unit shall be able to accept and process all the data states into digital signal that will be easy to format for display. The data expected to be processed are wind direction, altitude, pad angle, and wind speed.

23.2.2.2 Display Output

The Display Output unit shall be able to format the signal received from the Get Data unit into an appropriate format for display on the LCD.

23.2.3 Data Processing Layer

23.2.3.1 Verify Data

The unit shall be able to access and verify the accuracy of the data from accelerometer and anemometer.

23.2.3.2 Encapsulate Data

Encapsulate Data unit shall be able to convert data from raw form to wind speed in M/PH and wind direction in degree.

23.2.3.3 Set Data

Set Data unit shall be able to serve as a temporary storage to store calculated wind direction and speed as well as flight data.

23.2.3.4 Process Data

The unit shall be able to compute wind speed and wind direction from the encapsulate wind data and create tables for lookup.

23.2.4 IRBS Hardware Interface Layer

23.2.4.1 Get Data

The Get Data unit shall be able to store wind temporarily for further processing and uses by the servos.

23.2.4.2 Hardware Processing

Hardware Processing unit shall be able to tilt the servo to a specific angle and pan the servo to a required angle using wind data.

23.2.5 IRBS Network Layer

23.2.5.1 Get Data

The unit shall be able to store flight data temporarily before being converted into packets appropriate uses.

23.2.5.2 Send/Receive

Send/Receive unit shall be able to pack, unpack, and acknowledge the flight data received from the Get Data module and send the data to RRM system.

23.2.6 RRM Network Layer

23.2.6.1 Send/Receive

Send/Receive unit shall be able to unpack the data received from the IRBS system, unpack, acknowledge and send the data back to the IRBS system.

23.2.7 RRM Data Input Layer

23.2.7.1 Barometer Input

The Barometer Input shall be able to calibrate the analog digital input from the anemometer and convert it to digital signal for verification.

23.2.7.2 Accelerometer Input

The Accelerometer Input shall be able to detect and read the analog digital input from the accelerometer for verification.

23.2.8 RRM Data Processing Layer

23.2.8.1 Verify Data

The unit shall be able to access and verify the accuracy of the data from accelerometer and barometer.

23.2.8.2 Stabilization Processing

Stabilization Processing unit shall be able to counterbalance and compensate calculation for controlling the rocket fin.

23.2.8.3 Air Pressure Process

The Air Pressure Process unit shall be able to convert air pressure from the barometer to be used to compute altitude needed for successful landing of the rocket.

23.2.9 RRM Hardware Interface Layer

23.2.9.1 Hardware Processing

Hardware Processing shall be able to use the wind speed to compensate for the movement and turning of the fin by the servos.

23. - Acceptance Plan

23.1 - Overview

This section describes the minimum criteria that must be met by the Rocket Recovery System in order to be considered acceptable by the customer and other stakeholders.

23.2 - Packaging and Installation

The Rocket Recovery System shall contain the following physical components:

23.2.1 - **Intelligent Rotating Base Station**

- HSR – 1425CR Continuous Rotation Servo
- HS – 64MG Servo Motor
- ADXL326 – 5V Ready Triple-axis Accelerometer
- DDT500 Direct Drive Tilt System
- Adafruit Perma-Proto Quarter-sized Breadboard PCB

23.2.2 - **Launch Control Box**

- Arduino Mega 2560 R3 DEV-11061
- Davis Anemometer, Standard (#7911)
- Rocket Switch – SPST
- Toggle Switch and Cover – Illuminated (Red)
- Concave Button - Red
- RGB backlight positive LCD 16x2
- LED indicators
- Relay SPDT Sealed
- 9 Volt Battery
- Battery Holder
- Instruction Manual

23.2.3 - **Rocket Recovery Module**

- Arduino Uno
- ADXL326 – 5V Ready Triple-axis accelerometer (+- 16g analog out)
- BMP085 Barometric Pressure/Temperature/Altitude Sensor – 5V Ready
- HS – 645MG Servo Motor
- 9 Volt Battery
- Battery Holder

23.2.4 - **SD-12 Rocket**

- Nose Cone
- Body Tubes
- Parachute
- Shroud Lines

- Tube Coupler
- Shock Cord
- Launch Lugs
- Bulkhead
- Clipped Delta Fins
- Centering Rings

23.3 - Acceptance Testing

System testing shall be conducted to ensure that the Rocket Recovery System meets the acceptance criteria. The Rocket Recovery System shall go through module, subsystem, layer, integration, and overall system testing. The details of the testing shall be provided in the System Test Plan document.

23.4 - Acceptance Criteria

The following requirements must be met in order for the Rocket Recovery System to be considered acceptable.

Requirement No.	Name	Description
3.1	Rocket lands where launched from	The system will launch a model rocket and land it within a 50 foot radius from the area where it was launched.
3.2	Simple User Interface	The system will be easy for user to use. This will require less input from the customer thereby make the operation simple
3.3	Reusability	The system will be made of non-breakable components. The customer will be able to use the system again by changing the engine and putting it back together.
3.4	IRBS – Standby Mode	The base station will have a standby mode. The standby mode will be the mode used during setup and preparation prior to entering the preparation mode.
3.5	IRBS – Preparation Mode	The preparation mode will be the active state of the base station in which environment variables are read, calculations made, and proper positioning conducted to prepare for the launch stage.
3.6	IRBS – Launch Mode	The launch stage will last 30 seconds. In this stage there will be no more wind data collection and the aggregated wind data will be sent to the Rocket Recovery Module inside the SD-12 Rocket. The base station will be in its final launch position.
3.7	IRBS – Rocket Stability Section	To ensure stability of the rocket while on the base station during high winds. This section of the base station contains the rods that the SD-12 Rockets lugs ride along to guide it during the first few feet of the launch. There will be a second rod that runs perpendicular to the first and the rocket will have two sets of lugs that will ride along the two rods.
3.8	Low Powered	The system will use common everyday 9 volt batteries.
3.9	IRBS - Rotation	Based on the anemometer the IRBS will rotate to orient itself and

		the SD-12 rocket into the wind.
3.10	IRBS – Pad pitch	Based on the anemometer the IRBS will pitch the pad at an angle into the wind depending on its strength.
3.11	RRS – Abort Countdown	The countdown will be aborted if one or all of the switches are flipped down.
3.12	IRBS – Wind Speed Detection	The anemometer mounted on the IRBS will be used to feed wind speed data to the IRBS microcontroller. This will be used to compute the time and angle that the SD-12 Rocket will take on ascent.
4.1	Hardware	The packaging will include the Intelligent Rotating Base Station and the SD-12 Rocket. The Rocket will be equipped with a Rocket Recovery Module. The anemometer will be included in the package, and the user will have to attach it to the Intelligent Rotating Base Station. The user will have to buy engines, batteries, and wadding separately. The user will also have to do minor assembling.
4.2	Software	The software will be embedded in the Rocket Recovery Module and the Intelligent Rotating Base Station.
4.3	User Manual	A user manual will be included for user's assistance.
5.3	RRS – Battery Life	The Rocket Recovery System battery life should last at least one launch cycle.
5.4	RRS – Outdoor Use	The Rocket Recovery System will function outside in normal conditions.
5.5	IRBS Modes – Times	The Intelligent Rocket Base Station will have 3 modes with the following time constraints for each: standby, no time constraint. Preparation: 2 minutes minimum, 3 maximum. Launch: strictly 30 seconds.
5.6	RRM – Microcontroller instructions per cycle	The processing power of the microcontroller will be fast enough to make stability correction that ensure smooth flight through the end of the burn.
7.1	Documentation	The RRS will come with a setup manual that outlines in detail the setup and launch procedures. This manual will include safety guidelines to follow to ensure that the user is safe throughout the entire operation.
7.4	Launch Procedure	A launch procedure, with outlined checks at each mode of the IRBS, will be provided to ensure a successful launch.
8.1	Rocket Engine Power	The rocket must not use motor with more than 160 Newton-seconds of total impulse (an "H" motor of larger) or multiple motors that all together exceeds 320 Newton-seconds. It must also not use a motor with more than 80 Newtons average thrust.
8.2	Rocket Engine Propellant	The rocket engine must not exceed 125 grams of propellant.
8.3	Rocket Weight	The rocket must not weigh more than 1,500 grams including motor(s).
8.4	Rocket Materials	The rocket must use only lightweight, non-metal parts for the nose, body, and fins.